19th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - September, 2018

PAPER – 4: ENERGY PERFORMANCE ASSESSMENT FOR EQUIPMENT AND UTILITY SYSTEMS

Section - I: BRIEF QUESTIONS **Marks: 10 x 1 = 10**

(i) Section I contains **Ten** questions
(ii) Each question carries **One** mark

S-1	The capacity of a screw compressor cannot be controlled by discharge throttling. **True or False**
Ans	**True**
S-2	A package air conditioner of 5 TR capacity delivers a cooling effect of 4 TR. If Energy Efficiency Ratio (W/W) is 2.90, the power in kW drawn by compressor would be ___________
Ans	**=(4*3024)/860 = 14.065/2.90 = 4.85**
S-3	If the steam generation in a boiler is reduced to 45%, the radiation loss from the surface of the boiler will reduce by the same ratio. **True or False**
Ans	**False**
S-4	If the coal Gross Calorific Value is 4200 kcal/kg and specific coal consumption is 0.6 kg/kWh, what is the power station gross efficiency ?
Ans	**(860 /(4200 x 0.6)) x100 = 34.12%**
S-5	If the measured input power of a 90 kW motor is 45 kW, then the calculated loading of the motor is 50 %. **True or False**
Ans	**False**
S-6	The speed of an energy efficient motor will be more than the standard motor of same capacity because _______________ decreases.
Ans	**Slip**
S-7	O_2 % in flue gas is required in the direct method efficiency evaluation of a boiler. **True or False**
Ans	**False**
S-8	To minimize scale losses in a reheating furnace, the furnace should be operated at a negative pressure. **True or False**
Ans	**False**

S-9	The heat rate of a power plant will reduce when there is an increase in the inlet cooling water temperature to the condenser. **True or False**
Ans	**False**
S-10	A typical co-generation system in a cement plant will come under the category of topping cycle. **True or False**
Ans	**False**

.... End of Section - I ....

Section - II: SHORT NUMERICAL QUESTIONS **Marks: 2 x 5 = 10**

(i) Section II contains**Two** questions

(ii) Each question carries **Five** marks

L-1	A coal based power plant A is having a Gross Unit Heat Rate of 2400 kCal/kWh with Auxiliary powerconsumption of 8 % whereas Plant B of same size and make, has an operating Net Heat Rate of 2500 kCal/kWh. In your opinion, which plant is more efficient and why?
Ans	Gross Heat Rate of Plant A – 2400 kcal/kwh Auxiliary Power Consumption – 8% Net Heat Rate of Plant A = Gross Heat Rate/(100- APC) = 2400/(1-0.08) = 2608.70 kcal/kwh Therefore, Plant B is more efficient with a lower Net Heat Rate of 2500 kcal/kwh than that of Plant A (2608.70 kcal/kwh).
L-2	Milk is flowing in a pipe cooler at a rate of 0.85 kg/sec. Initial temperature of the milk is 55 °C and it is cooled to 18 °C using a stirred water bath with a constant temperature of 10 °C around the pipe. Specific heat of milk is 3.86 kJ/kg °C. Calculate the heat transfer rate (kCal/hr) and also LogrithmicMeanTemprature Difference (LMTD) of the exchanger.
Ans	Heat transfer in cooling milk = 0.85 * 3.86 * (55 – 18) = 121.4 kJ/sec = (121.4* 3600) = (437040 kJ/hr) / (4.18) = 104555 kcal/hr LMTD: DT1 = 55 – 10 = 45 °C DT2 = 18 – 10 = 8 °C LMTD of the heat exchanger = (45 – 8)/ ln (45 / 8) = 21.4 °C

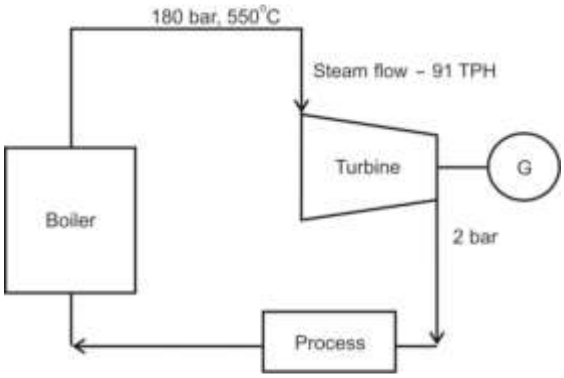
.... End of Section - II ....

Section - III: LONG NUMERICAL QUESTIONS **Marks: 4 x 20 = 80**

(i) Section III contains**Four** questions

(ii) Each question carries **Twenty** marks

N-1 The schematic and operating data of a steam turbine cogeneration plant with a back pressure turbine is given below.



Enthalpy of steam at 180 bar, 550 ^{0}C – 3420 kJ/kg

Exhaust steam enthalpy at isentropic expansion from 180 bar to 2 bar – 2430 kJ/kg

Enthalpy of boiler feed water – 504.7 kJ/kg

Efficiency of boiler - 80 %

Calorific value of coal – 4500 kcal/kg

Steam flow rate into the Turbine - 91 TPH

Turbine isentropic efficiency - 90 %

Generator efficiency - 98 %

Gear box efficiency - 97 %

Calculate: (each carries 5 Marks)

a) Electrical output from the generator in MW

b) Fuel consumption in Boiler in TPH

c) Energy Utilization factor of the cogeneration plant

d) Heat to power ratio of the cogeneration plant, kCal/kW

Ans

a) Electrical output from the generator in MW

Actual exhaust steam enthalpy = [3420 - (0.9 x (3420 - 2430))]

= 2529 kJ/kg

Turbine power output = 1 x (1000/3600)) x (3420 - 2529)]/1000

= 22.52 MW

Electrical output = (22.52 x 0.97 x 0.98)

= 21.4 MW

b) Fuel consumption in Boiler in TPH

	Fuel consumption in Boiler = (91,000 x (3420 – 504.7)) / (4.18 x 4500 x 0.80) = 17.6 TPH **c) Energy Utilization factor of the cogeneration plant** = [(21,400 x 860) + (91000 x ((2529 – 504.7)/ 4.18))] / (17,600 x 4500) = [(1,84,04,000 + 44069689) / (7,92,00,000)] = 0.79 **d) Heat to power ratio of the cogeneration plant, kCal/kW** Heat to power ratio, kcal/kW = (91000 x (2529 - 504.7)/4.18) / 21400 = 2059 kCal/kWh (or) = 2.39 $kW_{thermal}/kW_{electrical}$

N-2	In a process plant, the hot effluent having a flow rate of 63450 kg/hr at 80 ^{0}C from the process is sent to a finned tube air cooled heat exchanger for cooling. The outlet temperature of theeffluent from the heat exchanger is 38 ^{0}C. Air at a temperature of 30 ^{0}C enters the heat exchanger and leaves at 60 ^{0}C. The fan develops a static pressure of 30 mmWC. The operating efficiency of the fan is 65 % and fan motor efficiency is 90 %. The plant operates for 5000 hours per year. The management decided to replace the existing air-cooled heat exchanger with water-cooled Plate Heat Exchanger (PHE). **Following are the relevant data:** **Existing:** • Specific heat of air : 0.24 kcal/kg ^{0}C • Specific heat of hot effluent : same as water • Density of air : 1.29 kg/m^3 **Proposed:** • Cooling water pump efficiency : 75 % • Pump motor efficiency : 90 % • Effectiveness of water cooled heat exchanger : 0.4 • Cooling water inlet temperature : 25 ^{0}C • Total head developed by the cooling water pump : 30 m • Over all heat transfer coefficient of PHE : 22300 kcal/hrm^2 ^{0}C **Calculate the following:**

	•Annual energy savings due to replacement of existing air cooled plate heat exchanger by water cooled counter flow plate heat exchanger. (15 Marks) •Area of the proposed water cooled plate heat exchanger. (5 Marks)

Ans

Heat duty in hot fluid = M x Cp_{hot} x (Ti - To)

= 63450 x 1 x (80 - 38)

= **2664900 kcal / hr**

In a heat exchanger,

Heat duty in hot fluid = Heat duty in cold Air

Mass of the cold air = 2664900 / (0.24 X (60-30))

= **370125 kg/hr**

Existing System:

$$\text{Fan Shaft Power} = \frac{\text{Volume,m}^3\text{/s X Static Press mmWc}}{\text{102 X Fan Efficiency factor}}$$

$$= \frac{(370125/(3600 \times 1.29)) \times 30}{102 \times 0.65}$$

= **36.06 kW**

Motor Input Power = 36.06/ 0.9 = **40.07 kW**

Proposed System:

Effectiveness of water cooled heat exchanger= 0.4

Cold Water outlet temperature = T_{Wo}

Cold water inlet temperature = T_{Wi}

Hot effluent inlet temperature = $T_{Eff.in}$

Hot effluent outlet temperature = $T_{Eff.out}$

$$\text{Effectiveness} = \frac{T_{Wo} - T_{Wi}}{T_{Eff.in} - T_{Wi}}$$

Cold Water Outlet = (0.4 x (80 – 25)) + 25

= **47 ^{O}C**

$$\text{Mass flow rate of cooling water (M)} = \frac{\text{Heat duty in hot fluid}}{Cp \times (T_{Wo} - T_{Wi})}$$

$$= \frac{2664900}{1 \times (47 - 25) \times 1000}$$

= **121.13 m^3 /hr**

	Hydraulic Power Requirement for one Cooling Water Pump: $$= \frac{(\text{Flow in m}^3/\text{hr x Head in m x Density in kg/m}^3 \text{ x g in m/s}^2)}{(1000 \times 3600)}$$ $$= \frac{(121.13 \times 30 \times 1000 \times 9.81)}{(1000X3600)}$$ = 9.9 kW Pump input Power Requirement = 9.9 kW / 0.75 2 kW Pump Motor Input Power = 13.2 / 0.9 = 14.67 kW Thus savings = Power consumption by fans – Water Pumping Power = 40.07 – 14.67 = 25.4 kW Annual energy savings in kWh = 25.4 kW x 5000 hrs = 127000 kWh/annum **Calculations for LMTD for Proposed counter flow PHE:** LMTD for counter flow in PHE= {(80-47) – (38-25)} / ln {(80-47) / (38-25)} = **21.5 ^{O}C** Considering overall heat transfer coefficient (U) = 22300 kCal/hrm$^{2 0}$C Heat transfer Area = Q / (U x ΔT_{lmtd}) = 2664900 /(22300 x 21.5) = **5.56 m^2**

N3	In a process industry, the wet products are to be dried in a drier. The plant has a pressurizedhot water boiler which supplies hot water at 145 ^{0}C to the heating coils in the drier. The return water to the boiler is at a temperature of 110 ^{0}C. The boiler is fired by saw dustbriquettes. **The other relevant data are given below.** • Fuel firing rate = 375 kg/hr • O_2 in flue gas = 12.2 % • CO in flue gas = 189 ppm • CO_2 in flue gas = 8.5 % • Avg. exit flue gas temperature = 235 ^{0}C • Ambient temperature = 31 ^{0}C • Humidity in ambient air = 0.0204 kg / kg dry air • Gross Calorific Value of ash = 800 kCal/kg • Radiation & other unaccounted losses = 0.5 % • Specific heat of flue gas = 0.23 kCal/kg^{0}C **Fuel (briquettes) Ultimate Analysis (in %)** • Ash = 8.0 • Moisture = 7.5 • Carbon = 45.3 • Hydrogen = 4.4 • Nitrogen = 1.4 • Oxygen = 33.3 • Sulphur = 0.1 • Gross Calorific Value of saw dust briquette = 3300 kCal/kg Calculate the hot water circulation rate (m^3/hr) in the boiler.
An	1. Theoretical air required for complete combustion $= [(11.6 x C) + \{34.8 x (H_2 - O_2/8)\} + (4.35 x S)]/100$ kg/kg of coal = [(11.6 x 45.3) + {34.8 x (4.4 – 33.3/8)} + (4.35 x 0.1)] / 100 = **5.34 kg / kg of briquette**. 2. Excess air supplied Actual O_2 measured in flue gas = 12.2 % % Excess air supplied (EA) $= \frac{O_2\%}{21 - O_2\%} \times 100$ $= \frac{12.2\%}{21 - 12.2\%} \times 100$ = **138.6 %**

3. Actual mass of air supplied

$$= \{1 + EA/100\} \times \text{theoretical air}$$

$$= \{1 + 138.6/100\} \times 5.34$$

= **12.74 kg/kg of briquette**

4. To find actual mass of dry flue gas

Mass of dry flue gas = Mass of CO_2 +Mass of N_2 content in the fuel+ Mass of N_2 in the combustion air supplied + Mass of oxygen in flue gas + Mass of SO_2in flue gas

$$= \frac{0.453\,x\,44}{12} + 0.014 + \frac{12.74\,x\,77}{100} + \frac{(12.74 - 5.34)\,x\,23}{100} + \frac{0.001x64}{32}$$

= **13.19 kg / kg of briquette**

5. To find all losses

a) % Heat loss in dry flue gas (L1) $= \dfrac{m\,x\,C_p\,x(T_f - T_a)}{GCV\ of\ \ fuel}\ x\,100$

$$= \frac{13.19\,x\,0.23\,x\,(235 - 31)}{3300}\ \ x\ 100$$

= **18.75 %**

b) % Heat loss due to formation of water from H_2 in fuel (L2)

$$= \frac{9\ \mathrm{x}\ \mathrm{H_2}\ \ \mathrm{x}\,\{584 + \mathrm{C_p}\ (\mathrm{T_f}\ \text{-}\,\mathrm{T_a}\ )\}}{\mathrm{GCV\ of\ fuel}}\ x\ 100$$

$$= \frac{9\ \mathrm{x}\ 0.044\ \mathrm{x}\,\{584 + 0.45\,(235\,\text{-}\,31\,)\}}{3300}\ x\ 100$$

= **8.1 %**

c) % Heat loss due to moisture in fuel (L3)

$$= \frac{\mathrm{M}\ \ \mathrm{x}\ \ \{584 + \mathrm{C_p}\ (\mathrm{T_f}\ \text{-}\,\mathrm{T_a}\ )\}}{\mathrm{GCV\ of\ fuel}}\ x\ 100$$

$$= \frac{0.075\ \mathrm{x}\ \ \{584 + 0.45\,(235\,\text{-}\,31\,)\}}{3300}\ x\ 100$$

= **1.54 %**

d) % Heat loss due to moisture in air (L4) = $\frac{AAS\, x\, humidity\, x\, C_p\, x\, (T_f - T_a)}{GCV\ of\ fuel}\, x\, 100$

$$= \frac{12.74\, x\, 0.0204\, x\, 0.45\, x\, (235 - 31)}{3300}\, x\, 100$$

= **0.723 %**

e) % Heat loss due to partial conversion of C to CO (L5)

$$= \frac{\%CO\ x\ C}{\%CO + \%CO_2}\ x\ \frac{5654}{GCV\ of\ fuel}\ x\ 100$$

$$= \frac{0.0189\ x\ 0.453}{0.0189 + 8.5}\ x\ \frac{5654}{3300}\ x\ 100$$

= **0.172 %**

f) % Heat loss due to Ash (L6)

Gross Calorific Value of Ash =800 kCal/kg

Amount of Ash in 1 kg of coal = 0.08 kg/kg coal

Heat loss in bottom ash = 0.08 x 800

=**64 kcal/kg of coal**

% Heat loss in bottom ash = (64x 100) / (3300)

= **1.94 %**

g) % Heat loss due to radiation & other unaccounted losses (L7) = **0.5% (given)**

HWG efficiency by indirect method = 100- (L1+ L2+ L3+ L4+ L5+ L6+ L7)

=100-(18.75 + 8.1+ 1.54+ 0.723+ 0.172 +1.94+0.5)

= **68.28 %**

Hot water circulation rate in m^3/hr:

HWG efficiency % = $\frac{(\text{Mass of hot water}\ x\ C_p\ x\ \Delta T)}{\text{Mass of fuel}\ x\ \text{GCV of fuel}}\ x\ 100$

Mass of hot water = $\frac{375\, x\, 3300\, x\, 0.6828}{(145 - 110)\, x\, 1}$

=**24,141.86kg/hr**

=**24.142 m^3/hr**

N-4 **Answer any ONE of the following**

<table>
<tr><td>A)</td><td>
A 60 MW captive power plant (CPP) of a chemical plant has a coal fired Boiler, condensing steam Turbine and Generator. The CPP after meeting its auxiliary power consumption is exporting power to the chemical plant. The operating data of CPP is as follows:

Generator output : 60 MW
Auxiliary power consumption : 6 MW
Steam flow to the turbine : 231 Tons/hr
Steam inlet pressure and temperature : 105 kg/cm^2 (a) and 480 ^{0}C
Enthalpy of inlet steam at operating pressure and temperature : 793 kCal/kg
Enthalpy of feed water to boiler : 130 kCal/kg
Condenser exhaust steam pressure and temperature : 0.1 kg/cm^2(a) and 45.5 ^{0}C
Enthalpy of water at operating pressure and temperature of condenser : 45.5 kCal/kg
Latent heat of vaporisation of steam at operating pressure and temperature of condenser : 571.6 kCal/kg
Enthalpy of exhaust steam : 554 kCal/kg
GCV of coal used : 4240 kCal/kg
Efficiency of the boiler : 86.5 %

Based on the above data, calculate the following parameters of the power plant:
a) Gross Heat Rate (8 Marks)
b) Net Heat Rate (3 Marks)
c) Dryness fraction of exhaust steam (2 Marks)
d) Condenser heat load (3 Marks)
e) Specific coal consumption (2 Marks)
f) Overall efficiency (2 Marks)
</td></tr>
<tr><td>Ans</td><td>
(a) Gross heat rate

$$\text{Gross heat rate} = \frac{\text{Coal consumption (kg/hr)} \times \text{GCV of coal (kcal/kg)}}{\text{Generator output (kw)}} \quad \text{--------------(1)}$$
Given : Coal consumption=?
GCV of coal=4240 Kcal/kg
Generator output= 60 MW

Boiler efficiency= Q (H-h)/ (q x GCV) --------------(2)

Where, Q= Quantity of steam generation (kg/hr)=231x1000
H= Enthalpy of steam (Kcal/kg) =793
h=Enthalpy of boiler feed water (kcal/kg) =130
q=Coal consumption (kg/hr) =?
Boiler efficiency=0.865
Substituting the given values in equation (2) we get,
0.865=(231 x 1000 x (793—130))/q x 4240
q= 41758 kg/hr
</td></tr>
</table>

B)	Substituting the calculated value of q in equation (1) we get, **Gross heat rate= (41758 x 4240) / (60x1000) =2950.9 kcal /kWh** **(b) Net heat rate** Net heat rate = Gross heat rate / 1—(% Auxiliary Power consumption/100) ----------------------(3) Auxiliary consumption =6 MW Generation= 60 MW % Auxiliary consumption=(6/60) x 100 = 10% Substituting the values in the equation (3) we get, **Net heat rate= 2950.9/(1—10/100)= 3278.8 kCal/kWh** **(C) Dryness fraction of exhaust steam** Enthalpy of exhaust steam = Enthalpy of feed water + Dryness fraction of steam x L.H. of vaporisation of steam Substituting the given values in the above, we get 554= 45.5+ dryness fraction of steam x 571.6 **Dryness fraction of steam= (554—45.5)/571.6 = 0.889** **(d) Condenser heat load** Heat load on condenser= Steam flow rate x L.H of vaporisation of steam x dryness fraction of steam = 231x 1000 x 571.6 x 0.889 **=117383.2 MCal/hr** **(e) Calculation of specific coalconsumption** Specific coal consumption = Total coal consumption/Gross generation = 41758 kg/hr / (60 x 1000) kW **= 0.696 kg/kWh** **(f) Calculation of overall efficiency of plant** Overall efficiency= 860/Gross heat rate, kCal/kWh -----------------------(4) Substituting the values we get**, 860/2950.9 =29.14%** **(OR)** Overall efficiency = (Generator Output, kW x 860 kCal/kWh) /(Mass flow rate of coal kg/hr x GCV of coal,kCal/kg) = (60 x 1000 x 860)/(41758 x 4240) **=29.14%**

OR

B)	In the energy audit of a 6-stage Preheater (PH) section of a 4000 TPD (clinker) Cement kiln operating at full load, the following were the field measurements taken.

S.No.	Description	Value
1.	Reference temperature (^{0}C)	0
2.	Reference pressure and the Barometric pressure (mmWG)	10323
3.	Average Dynamic Pressure (mmWC)	17.1
4.	Static Pressure at Fan Inlet (mmWC)	-860
5.	Static Pressure at Fan outlet (mmWC)	-16
6.	Temperature (^{0}C)	328
7.	Density of the PH Gas (NM^3/kg), at reference condition	1.422
8.	Pitot Tube constant	0.854
9.	Diameter of PH Duct (m)	3.2
10.	Cp of PH Gas (kcal/kg^{0}C)	0.245
11.	Power Input to the PH fan motor (kW)	1812
12.	PH fan Motor Efficiency (%)	95
13.	GCV of coal (kCal/kg)	5600
14.	Annual Operating Hours	7300
15.	Cost of Coal (Rs./Ton)	4836

a) Estimate the specific heat losses (kCal/kg clinker) carried away by PH gases. (5 Marks)

b) Estimate the PH fan Efficiency. (5 Marks)

c) Estimate the envisaged specific fuel savings (kCal/kg clinker), annual fuel savings and annual monetary savings by reduction in PH gas temperature to 290 ^{0}C by appropriate modification in the PH cyclones. (5 Marks)

d) Estimate energy savings in fan power consumption in the proposed case where PH exit temperature is reduced to 290 ^{0}C. Also consider the static pressure at the fan inlet will reduce by 8 % from the present level due to PH modification (Fan and motor efficiency in both the cases are same). (5 Marks)

Ans:

a) Specific heat losses by PH gases(kCal/kg clinker)

Density of gas at Present operating Conditions (kg/m^3)	$\rho_{t,p} = \rho_{stp} \times \frac{10323 * -P_S}{10323} \times \frac{273}{273+t_e}$ kg/m^3 = 1.422*(273/(273+328))*((10323 -860)/10323) kg/m^3	0.59
Velocity of PH Gas (m/s)	Velocity =$P_t \times \sqrt{(2g(\Delta P_{rms})_{avg} / \rho_{t,p})}$ m/sec =0.854 * ((2 * 9.81 * 17.1/0.59))$^{0.5}$	20.36
Area of the PH Duct (m^2)	= Pi/ 4 * D^2 = 3.14 * (3.2^2)/4	8.04

Flow rate of the PH Gas (m^3/hr)	= Area * Velocity = 8.04 * 20.36 *3600 m^3/hr	589299.8
Flow rate of the PH Gas (Nm^3/hr)	= Flow rate of the PH Gas (m^3/hr) x (0.59/1.422) = 589299.8 X (0.59/1.422)	244505.5
Specific PH Gas generation ($Nm^3_{PH\ gas}/kg_{Clinker}$)	= Flow rate of Ph gas (Nm^3/hr) / Clinker Production (kg/hr) = 244505.5/ ((4000x1000)/24)	1.467
Specific PH Gas generation ($kg_{PH\ gas}/kg_{Clinker}$)	= Specific PH Gas generation ($Nm^3_{PH\ gas}/kg_{Clinker}$) x 1.422 kg/$Nm^3$ =1.467 x 1.422	2.086
Specific Heat Loss in existing case (kcal/$kg_{Clinker}$)	= m C_p (T_{ph}-T_{ref}.) =2.086*0.245*(328-0)	167.6
b) PH fan efficiency		
Air Power (kW)	= ((Q (m^3/hr)/3600)x (P_{st}(mmWC)))/102 = (589299.8/3600)* (-16+860)/102	1354.5
Fan Efficiency (%)	= Air power*100/(motor power *motor effi) = (1354.5*100)/(1812*0.95)	78.7
c) Envisaged fuel and monetary savings		
Specific Heat Loss in the proposed case (Kcal/$Kg_{Clinker}$)	= M C_p ($T_{ph\text{-}new}$-T_{ref}.) =2.086 * 0.245 * (290-0)	148.21
Fuel Savings (Kcal/Kg Cli	=old heat loss/kg cli- new heat loss/kg cli =167.6-148.21	19.39
Annual Fuel Savings	=Clinker prod. * run hrs/yr* heat saving/kg cli /coal gcv =166.67*7300*19.39/5600	4212.79
Annual Monetary savings (Rs. Lakhs/yr)	=fuel savings in tons * fuel cost in (Rs. Ton) = (4212.79 *4836)/100000	203.73
d) Fan energy savings		
Envisaged static pressure at Fan Inlet after PH modification (mmWC)	= 92% of Original Static pressure at Fan inlet (reduction in Friction loss due to temperature reduction- given) = 92% * 860	-791.2
Envisaged Fan Flow after PH modification	= Flow (Nm3/hr) * ((273+$T_{ph\text{-}new}$)/273) * (10323/(10323+$P_{st\text{-}new}$)) = 244505.5* ((273+290)/273)*(10323/(10323-791.2))	546091.5
Fan efficiency (%)	Already estimated above (considering the same)	78.7
Fan motor Input power in the proposed case (kW)	= ((Q (m^3/hr)/3600)x (P_{st}(mmWC)))/102 = ((546091.5/3600)* (-16+791.2))/(102*.787*.95)	1541
Fan Power saving (kW)	=Fan power (old-new) =1812 - 1541	271
Annual Energy saving (Lakh kWh/yr)	=(power saved * Annual operating hrs)/10^5 = (271 * 7300) / 10^5	19.783

OR

C)	A building is currently using Vapour Compression Refrigeration (VCR) chillers for meeting its cooling requirements. The following are the existing data pertaining to the building. **Existing System:** • Total Power drawn from grid for the whole building including chiller loads : 1300 kW • Grid Power required for VCR : 300 kW • Building cooling load : 7,56,000 kCal/hr • Cost of Grid Power : Rs.8 /kWh The management proposes to install a natural gas engine with a Waste Heat Recovery Boiler (WHRB), which will generate power as well as steam for an operating Vapour Absorption Machine (VAM). A part of the total chilling load and power requirement of the building is proposed to be met by this cogeneration system. The following are the data for the proposed system. **Proposed System:** • Total power generated from gas engine co-gen plant : 1000 kW • Gas engine efficiency : 40 % • Heat absorbed for steam generation in WHRB (as a % of heat input to gas engine) : 21 % • Specific steam consumption for VAM : 5 kg/TR • Calorific value of Natural Gas : 8500 kcal/sm^3 • Cost of Natural Gas : Rs.40/sm^3 • Annual operating hours : 4000 • Total enthalpy of steam : 660 kCal/kg • Feed water temperature to WHRB : 60 ^{0}C **Calculate the following:** • Cost of generating one unit of electricity from the gas engine ? (5 marks) • TR generated from Vapour Absorption Chiller driven by WHRB generated steam? (5 Marks) • Total energy cost of existing & proposed system and state whether the proposed scheme is viable ? (10 marks)
Ans	1. Cost of generating one unit of electricity from gas engine? • Fuel Consumption = 1000 kW X 860 / (0.4 X 8500) = **252.94 sm^3/hr** • Cost per unit of electricity from gas engine = (252.94 sm^3/hr X 40 Rs./ sm^3) / 1000 kW

= **Rs.10.12/ kWh**

2. TR generated from VAM driven by WHRB generated steam?

- Heat absorbed by WHRB for Steam generation = 21% x (252.94 x 8500)
  = **451497.9 kcal /hr**

- Amount of steam generated = 451497.9/(660-60)
  = **752.49 kg/hr**

- TR generated by VAM = 752.49/5 = **150.49 TR**

3. Techno-economic viability of the proposed scheme?

- Present cost of Electricity (Grid) = 1300 x 8 = **10,400 Rs./hr**

Proposed Scheme

- Cost of NG for Electricity = 252.94 sm^3/hr X 40 Rs./ sm^3
  = **10,118 Rs. /hr**

- TR required by the building = 756000/3024
  = **250 TR**

- Energy performance of chiller (VCR) = 300/250
  = **1.2 kW/TR**

- Cost of Electricity from Grid to meet the balance chiller load
  = (250-150.49) x 1.2 x 8
  = **955.30 Rs./ hr**

- Total energy cost with proposed system = 10118 +955.30
  = **11,073 Rs./hr**

Proposed project is not viable, because total cost is more in proposed scheme than in present scheme.

OR

D) In a textile process unit, a five chamber stenter is installed for drying the cloth. The inlet and outlet conditions of the cloth are shown in the figure below. The production output of the stenter is 10,000 kgs/day.

The heat input to the stenter is provided by a thermic fluid heater fired by fire wood as fuel. Gross Calorific Value (GCV) of Fire Wood is 3500 kcal/kg. The efficiency of the thermic fluid heater is 70% and distribution loss in the thermic fluid system is 20,000 kcal/hr. The average

	fire wood consumption rate is 427 kg/hr. Calculate the following: (each carries 10 Marks) a) Drier efficiency b) Fuel savings in thermic fluid heater if the inlet moisture is reduced from 60 % to 50 % by mechanical squeezing. (Assume that drier efficiency does not change)

Ans

Calculation of Stenter Efficiency

$$\text{Stenter Efficiency, \%} = \frac{W \times (m_{in} - m_{out}) \times \{(T_{out} - T_{in}) + 540\}}{Q_{in}} \times 100$$

OR

$$\text{Stenter Efficiency, \%} = \frac{(\text{moisture removed from fabric}) \times \{(T_{out} - T_{in}) + 540\}}{Q_{in}} \times 100$$

Where,

W =Bone dry weight of the fabric, kg/hr

m_{in} = kg moisture / kg bone dry fabric at inlet

m_{out} = kg moisture / kg bone dry fabric at outlet

Q_{in} = Thermal energy input to the stenter (kCal/hr)

(a) Drier Efficiency

Amount of moisture removed:

Bone dry weight of fabric = (10,000 x (95%)) = 9500 kg/day
Hence, Total weight of inlet fabric = (9500)/(0.4/1.0)
= 23,750 kg/day
Inlet Moisture weight = (23,750 – 9500)
= 14,250 kg/day

OR

m_{in} = (14,250 kg/day) / (9500 kg/day)
= 1.50 kg/kg dry fabric

Outlet Moisture weight = 10000 - 9500
= 500 kg/day

OR

m_{out} = (500 kg/day) / (9500 kg/day)
= 0.053 kg/kg dry fabric

Moisture removed from fabric in Stenter

$m_{in} - m_{out}$ = 1.5 – 0.053
= 1.447 kg/kg dry fabric
W x ($m_{in} - m_{out}$) = 9500 x 1.447
=13747 kg/day
= 573 kg/hr

OR

Moisture at I/L– moisture at O/L = (14,250-500)
= 13,750 kg/day
= 573 kg/hr

Heat required for removing the moisture = 573 x {(80-28) + 540}
= 3,39,216 kcal/hr

Heat input to the Thermic Fluid = (Firewood consumption rate x Calorific value x thermic fluid heater efficiency)
= (427 kg/hr x 3500 kcal/kg x 70%)
= 10,46,150 kcal/hr

Heat input to the Drier = 10,46,150 – 20,000 = 10,26,150 kcal/hr
Stenter Efficiency (%) = (Heat reqd. for removing moisture / Heat input to the stenter)
= (3,39,216 / 10,26,150) x 100
= 33%

(b) Fuel savings if the inlet moisture reduced from 60 to 50%

Moisture removed in Drier with **50% input moisture**

(At 50 % moisture : Bone dry weight = moisture weight = 9500 kg)

Moisture removed from the fabric in the Stenter = Inlet moisture – Outlet moisture
= (9500-500)
= 9000 kg/day
= 375 kg/hr

Drier efficiency, 33 %

= [375 kg/hr x {(80-28) ^{0}C + 540 kCal/kg}] / [(Fuel consumption kg/hr x 0.70 x 3500 kCal/kg) – 20000kCal/hr]

Therefore, Fuel consumption, kg/hr (for reduction of inlet moisture)

= [{(375 kg/hr x {(80-28) ^{0}C + 540 kCal/kg}) /0.33} + 20000] / (0.70 x 3500)

= (672727 + 20000)/ (0.70 x 3500)

= 283 kg/hr

Fuel Savings = 427 – 283 = 144 kg/hr = 3456 kg/day

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