PAPER-1 COLOR CODE : GREEN

24th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER, 2024
PAPER - 1 : GENERAL ASPECTS OF ENERGY MANAGEMENT & ENERGY AUDIT

Date : 28.09.2024 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

1. **Calculate the reduction in CO2 emissions if energy efficiency measures save 1000 kWh, assuming 0.8 kg CO2/kWh.**
   a) 800 kg
   b) 1250 kg
   c) 625 kg
   d) 1000 kg

2. Which of the following is not true, equivalent to 1 atm pressure?

   a) 1 atm = 101.3 kPa
   b) 1 atm = 10332 mmWC
   c) 1 atm = 14.7 psi
   d) 1 atm = 0.98 kg/cm2

3. Redwood Seconds is measure of _____

   a) Density
   b) Viscosity
   c) Specific Gravity
   d) Flash Point

4. For calculating plant energy performance which of the following data is not required
   a) Current year production
   b) Capacity Utilization
   c) Reference year production
   d) Reference year Energy use

5. The internal rate of return is discount rate for which NPV is
   a) Positive
   b) Zero
   c) Negative
   d) All of the above

6. Transit time method is used in which of the instrument
   a) Lux Meter

b) Ultrasonic Flow Meter
c) Pitot Tube
d) Fyrite

7. Which of the following GHG has the longest atmospheric life time
   a) Carbon dioxide (CO_2)
   b) Sulphur Hexafluoride (SF_6)
   c) Chloroflurocarbons (CFC)
   d) Perfluorocarbons (PFC)

8. What is the heat content of 500 liters of water at 6°C in terms of the basic unit of energy in kilojoules?
   a) 12000
   b) 3000
   c) 500
   d) None of the above

9. The number of moles of water contained in 72 grams of water is
   a) 2
   b) 3
   c) 4
   d) 5

10. Which of the following is not objective of Demand Side Management?
    a) Managing Demand by DISCOM to reduce peak demand
    b) Increasing Load of Generator to meet Peak demand
    c) Reducing Capital need for Power Capacity Expansion
    d) None of the above

11. Which of the following has the lowest energy content in terms of MJ/kg
    a) LPG
    b) Diesel
    c) Bagasse
    d) Furnace Oil

12. Heat transfer in an air-cooled condenser occur predominately by
    a) Conduction
    b) Convection
    c) Radiation
    d) All of the above

13. The force field analysis in energy action planning considers
    a) Positive forces only
    b) Negative Forces only
    c) No forces
    d) Both Positive and Negative forces

14. To arrive at the relative humidity at a point we need to know _____ of air
    a) DBT
    b) WBT
    c) Dew point
    d) Both A and B

15. Which statement is false regarding Critical path
    a) CP is longest duration path
    b) It identifies minimum time to Complete the project
    c) Activities lies on it cannot be delay
    d) It is maximum time required to complete the project

16. The roto axis is aligned with wind direction in windmill by _____control?
    a) Yaw
    b) Pitch
    c) Disc Break
    d) Both A and B

17. For activity in project, Latest start time is 8 weeks and Latest Finish time is 12 Weeks. If the earliest finish time is 9 Weeks, Slack time for the activity is
    a) 1 Week
    b) 3 Weeks
    c) 4 Weeks
    d) 7 Weeks

18. Which techniques takes care of time value of money in evaluation
    a) Payback Period
    b) IRR
    c) NPV
    d) Both B and C

19. If asset depreciation is considered, then the net operating cash inflow will be
    a) Lower
    b) Higher
    c) No effect
    d) None of the above

20. One Silicon cell in PV modules typically produces
    a) 0.5 V
    b) 1.0 V
    c) 1.5 V
    d) 2.0 V

21. When the evaporation of water from wet substance is zero, the relative humidity of air is likely to be
    a) 0%
    b) 50%

c) 100%
d) Unpredictable

22. The energy conversion efficiency of solar cell does not depend on
    a) Solar Energy Insolation
    b) Inverter
    c) Area of the Solar Cell
    d) Maximum Power Output

23. Energy Intensity is ratio of
    a) Fuel Consumption/GDP
    b) GDP/Fuel Consumption
    c) GDP/Energy Consumption
    d) Energy Consumption/GDP

24. In inductive and resistive combination circuit, the resultant power factor under AC supply will be
    a) Less than Unity
    b) More than Unity
    c) Zero
    d) Unity

25. If wind speed triples, the energy output from wind turbine will be
    a) 3 Times
    b) 6 Times
    c) 9 Times
    d) None of the above

26. If we heat air without changing absolute humidity, % relative humidity will
    a) Increase
    b) Decrease
    c) No change
    d) Can't Say

27. Among which of the following fuel the difference between the GCV and NCV is maximum
    a) Coal
    b) Furnace Oil
    c) Natural Gas
    d) Rice Husk

28. Which among the following factors is most appropriate for adopting EnMS?
    a) To improve their energy efficiency
    b) To reduce cost
    c) To increase productivity
    d) Systematically manage their energy use

29. The Ozone layer in stratosphere act as an efficient filter for

a) UV-B Rays
b) UV-C Rays
c) X- Ray
d) Gamma Rays

30. An induction motor with 30 kW rating and efficiency of 85% in its name plate means
a) It will draw 35.29 kW at full load
b) it will always draw 30 kWat full load
c) it will draw 25.5 kW at full load
d) it will draw 28.23 kW at full load

31. Which of the following macro factors is used in the sensitivity analysis of project finance
a) Change in Tax rate
b) Change in O & M Cost
c) Change in Debt : equity Ratio
d) Change in forms of Financing

32. An indication of Sensible heat content in air-water vapour mixture is
a) Wet bulb temperature
b) Dry bulb temperature
c) dew point temperature
d) density of air

33. Energy content in 2500 kgs of coal with a calorific value of 4000 kcal/ kg in terms of toe would be
a) 1 toe
b) 10 toe
c) 100 toe
d) 1000 toe

34. Reserve per production (R/P) is estimated as
a) Reserves remaining at end of year X production in the year
b) Reserves remaining at end of year / production in the year
c) production in year / Reserves remaining at end of the year
d) None of the above

35. In a fuel cell, ___ combines with ____ to generate electricity and ____ comes out as a by-product.
a) Hydrogen, Oxygen, water
b) Hydrogen, Nitrogen, nitrous oxide
c) Carbon, hydrogen, methane
d) Carbon, oxygen, carbon dioxide

36. A manufacturing plant consumes 5 tonnes of coal (CV = 4000 kCal/ kg) to produce 25 tonnes of cement. The Specific Energy Consumption (SEC) of the plant shall be
a) 100 kcal/ kg of cement
b) 200 kcal/ kg of cement
c) 400 kcal/ kg of cement

d) 800 kcal/ kg of cement

37. A solution of common salt in water is prepared by adding 25 kg of salt to 100 kg of water. The concentration of salt in this solution as a weight fraction shall be
    a) 10%
    b) 15%
    c) 20%
    d) 25%

38. An electric iron of power 2000 watts is used for a total of 120 minutes per month. Compute its monthly electricity consumption
    a) 2.0 kWh
    b) 2.4 kWh
    c) 4.0 kWh
    d) 24.0 kWh

39. The dryness fraction (x) of superheated steam will be
    a) x = 0.8
    b) x = 0.9
    c) x = 1
    d) x = 0

40. **Which entity is responsible for implementing the Energy Conservation Act 2001?**
    a) Ministry of Renewable Energy
    b) **Bureau of Energy Efficiency (BEE)**
    c) Central Pollution Control Board
    d) National Productivity Council

41. **Which of the following is a measure included in the Energy Conservation Act 2001?**
    a) Energy audits
    b) Energy-saving certificates
    c) Standards and labelling
    d) **All of the above**

42. **Calculate the energy consumed by a 200-watt appliance used for 5 hours a day over 30 days.**
    a) 30 kWh
    b) 27000 kCal
    c) 6500 kJ
    d) 30 kJ/h

43. **Which of the following is a non-renewable energy source?**
    a) Solar
    b) Wind
    c) Biomass
    d) **Coal**

44. **How is energy efficiency typically improved in industrial processes?**
    a) Reducing production rates
    b) **Optimizing equipment performance**

c) Increasing labour
d) None of the above

45. **Which of the following is a typical step in an energy audit?**
    a) Data collection
    b) Analysis
    c) Reporting
    d) **All of the above**

46. **Which tool is commonly used for measuring power factor ?**
    a) Thermometer
    b) Hygrometer
    c) Anemometer
    d) None of the above

47. **What is the payback period in energy management?**
    a) Time taken to identify savings
    b) Time taken to report savings
    c) **Time taken to recover the investment through savings**
    d) All of the above

48. **Which of the following is a method for financing energy efficiency projects?**
    a) Loans
    b) Leasing
    c) Performance contracting
    d) **All of the above**

49. **What is the primary financial metric used to evaluate energy projects?**
    a) Gross margin
    b) **Net present value (NPV)**
    c) Revenue
    d) Operating income

50. **Which principle is energy monitoring and targeting based on?**
    a) Energy consumption is constant
    b) **You can't manage what you don't measure**
    c) Energy consumption is unpredictable
    d) Production rate has no effect

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

Section – II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

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

S1	A 10 HP rated induction motor, with nameplate details indicating 415V, 12 amps, and a power factor (PF) of 0.9, is being audited. During the audit, the monitoring equipment displays a reactive power of 2 kVAr and a power factor of 0.758. Calculate the percentage loading of the motor at the time of the test.

	Solution: PF = kW/KVA (1) $(KVA)^2 = (kVAr)^2 + (kW)^2$ (2) Given kVAr = 2 and PF=0.758 Solve for kW in eqn (2) using eqn (1) we get, kW measured = 2.32kW Motor rated input kW= 1.732VIcos ₵ = 1.732*0.415*12*0.9=7.76 kW Percentage loading of motor= kW measured /rated input kW * 100 = 2.32/7.76 * 100 =**29.88%**
S2	A renovation and modernization (R&M) program of a 1 MW coal-fired thermal power plant was carried out to enhance the operating efficiency from 28% to 32%. The specific coal consumption was 0.7 kg/kWh before R&M. For 7000 hours of operation per year and assuming coal quality remains the same, calculate a) The coal saving per year in tonnes b) The expected avoidance of CO2 into the atmosphere in Tons/year if the emission factor is 1.3 kg CO2/kg coal. **Solution:** a) Coal consumption per kWh with 32 % efficiency = 28 x 0.7 / 32 = 0.61 kg/kWh Saving in coal = (7000 x 1000 x (0.7 – 0.61) = 630000 kg b) Expected Avoidance = 63000 x 1.3 = 819 Tons/year
S3	A drilling machine drawing continuously 5 kW of input power and with an efficiency of 50%, is used in drilling a bore in an aluminum block of 5 kg of mass. A portion of energy imparted to the block is lost to surroundings and the balance is absorbed by the block in its uniform heating. A 45 °C rise in temperature of the block was observed at the end of 100 seconds and the specific heat of aluminum block is 900 J/kgK. What percentage of drilling machine output power is lost to the surroundings? **Solution:** Power input to the drilling machine = 5kW Power output of drilling machine = 5 x 0.5 = 2.5 kW

	Energy used in drilling of bore, Q = 2.5x1000x100 = 250000 J Effective energy absorbed by block,Q' = m x c p x (temp rise)= 5*900*45 = 202500J Percentage of energy utilized for heating = 202500/250000= 81% Percentage of energy lost to surroundings = 100-81= **19%**
S4	Calculate the investment of the project having IRR of 16% and having respective annual savings of Rs 15,000, Rs. 18,000 and Rs. 20,000 at the end of the first, second and third year. **Solution:** NPV = (15000/1.16)+18000/(1.16x1.16)+(20000/(1.16x1.16x1.16)) = 12931 + 13377 + 12813 = 39,121/-
S5	In a heat exchanger steam is used to heat 5 kL/ hour of furnace oil from 30^0C to 90^o C. Specific heat of furnace oil is 0.22 kcal/ kg/^{O}C and the specific gravity of furnace oil is 0.95. a) How much steam per hour is required, if steam used is having latent heat of 510 kcal/kg? b) If steam cost is Rs.3.40/kg and electrical energy cost is Rs.6/kWh, which type of heating would be more economical in this particular case? **Solution:** a) Total heat required = m Cp ΔT = (5 x1000x 0.95) * 0.22 * (90-30) = 62,700 kcal/hr Latent heat of steam = 510 kcal/kg Amount of steam required = 62700/510 = **123 kg/hr** b) Steam cost = 123 x Rs.3.40 = Rs.**417.9/hr** Amount of electricity required = 62700/860 = 72.9 kWh Cost of electricity = 72.9 x Rs. 6 = Rs.**437.4/ hr** **Steam heating will be more economical**
S6	a) Lower energy intensity of a country need not necessarily mean higher energy efficiency. Explain? b) Why is energy intensity expressed taking into account purchase power parity? **Solution:**

	a) Page No 17 **b) Page No 18**
S7	a) Differentiate between commercial and non-commercial energy with an example for each. b) Differentiate between renewable and non-renewable energy with an example for each. **Solution:** **a) Page No 2** **b) Page No 3**
S8	a) Write down the parameters, which can be measured by the following instruments. • Stroboscope • Sling Psychrometer • Fyrite • Pitot Tube b) An electric resistive heater consumes 3.6 MJ when connected to a 200 V supply for one hour. Find the rating of the heater and the current drawn from the supply. **Solution:** a) Stroboscope – Non Contact Speed measurement Sling Psychrometer – Dry and wet bulb temperature Fyrite – To measure O2 and CO2 Pitot Tube – To measure pressure in gas ducts **b)** Energy=power x time Power=Energy / time = 3.6×10^6 J/(60 x 60) = 1kW Current = Power / Voltage = 1000 W/200V = 5 Ampere

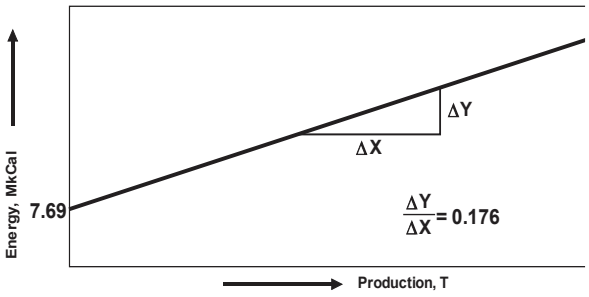
..... End of Section II .....

Section – III: LONG DESCRIPTIVE QUESTIONS Marks: 6 x 10 = 60

(i) Answer all Six questions

(ii) Each question carries Ten marks

L1 | Using the details given below, construct the CUSUM table and calculate the annual savings in MTOE, considering 10,000 kcal/kg of fuel.



Month	Electrical Power in kWh	Production (T)
Apr	90981	493
May	94993	335
Jun	88010	297
Jul	85374	493
Aug	88741	381
Sep	88450	479
Oct	90780	585
Nov	82216	440
Dec	90612	318
Jan	85672	234
Feb	74939	239
Mar	83823	239

Solution:

Month	Electrical Power in kwhr	Total Energy in mkcal (y) Eact	Production (x)	Ecal (0.176 X +7.69=Y) in mkcal-Base Line	Eact-Ecal in mkcal	Cusum in mkcal
Apr	90981	78.24	493	94	-16	-16
May	94993	81.69	335	67	15	-1
Jun	88010	75.69	297	60	16	15
Jul	85374	73.42	493	94	-21	-6
Aug	88741	76.32	381	75	2	-5
Sep	88450	76.07	479	92	-16	-21
Oct	90780	78.07	585	111	-33	-53
Nov	82216	70.71	440	85	-14	-68
Dec	90612	77.93	318	64	14	-54
Jan	85672	73.68	234	49	25	-29
Feb	74939	64.45	239	50	15	-14
Mar	83823	72.09	239	50	22	8

Savings in MTOe = 8 x 10^6 / 10^7
= 0.8 MTOe

L2 You are evaluating a multi-phase investment project with the following cash flows in over a 5-year period. The project includes an initial investment of Rs.20 Lakhs, an additional investment of Rs.5 Lakhs in Year 3, and a salvage value of Rs.3 Lakhs at the end of Year 5. The yearly savings are given below:

Year	Cash Flow (Rs. Lakhs)
1	6
2	7
3	4
4	9
5	12

Calculate the Internal Rate of Return (IRR) for the project.

Solution:

The cash flows for each year are as follows:

Year	Cash Flow (Rs. Lakhs)
0	-20
1	6
2	7
3	-1 (4-5)
4	9
5	15 (12+3)

The IRR is the discount rate that makes the Net Present Value (NPV) of these cash flows equal to zero.

$$NPV = -20 + \frac{6}{(1+r)^1} + \frac{7}{(1+r)^2} + \frac{-1}{(1+r)^3} + \frac{9}{(1+r)^4} + \frac{15}{(1+r)^5} = 0$$

Let's start with, say r=15% or 0.15.

$$\begin{aligned} NPV &= -20 + \frac{6}{(1+0.15)^1} + \frac{7}{(1+0.15)^2} + \frac{-1}{(1+0.15)^3} + \frac{9}{(1+0.15)^4} + \frac{15}{(1+0.15)^5} \\ &= -20 + \frac{6}{1.15} + \frac{7}{1.3225} + \frac{-1}{1.520875} + \frac{9}{1.74900625} + \frac{15}{2.0113571875} \\ &= -20 + 5.217 + 5.293 + (-0.657) + 5.146 + 7.457 \\ &= -20 + 22.456 = 2.456 \end{aligned}$$

Since the NPV is positive, we need a higher rate. Let's try $r = 20\%$ or 0.20.

$$\begin{aligned} NPV &= -20 + \frac{6}{(1+0.20)^1} + \frac{7}{(1+0.20)^2} + \frac{-1}{(1+0.20)^3} + \frac{9}{(1+0.20)^4} + \frac{15}{(1+0.20)^5} \\ &= -20 + \frac{6}{1.20} + \frac{7}{1.44} + \frac{-1}{1.728} + \frac{9}{2.0736} + \frac{15}{2.48832} \\ &= -20 + 5 + 4.861 + (-0.578) + 4.339 + 6.027 \\ &= -20 + 19.649 = -0.351 \end{aligned}$$

Since the NPV is negative, we need a slightly lower rate. Let's try $r = 19\%$ or 0.19.

$$NPV = -20 + \frac{6}{(1+0.19)^1} + \frac{7}{(1+0.19)^2} + \frac{-1}{(1+0.19)^3} + \frac{9}{(1+0.19)^4} + \frac{15}{(1+0.19)^5}$$
$$= -20 + \frac{6}{1.19} + \frac{7}{1.4161} + \frac{-1}{1.684319} + \frac{9}{2.0043401} + \frac{15}{2.384163719}$$
$$= -20 + 5.042 + 4.942 + (-0.594) + 4.490 + 6.292$$
$$= -20 + 20.172 = 0.172$$

Since the NPV is positive, we need a slightly higher rate. Let's try $r = 19.2\%$ or 0.192.

$$NPV = -20 + \frac{6}{(1+0.192)^1} + \frac{7}{(1+0.192)^2} + \frac{-1}{(1+0.192)^3} + \frac{9}{(1+0.192)^4} + \frac{15}{(1+0.1}$$
$$= -20 + \frac{6}{1.192} + \frac{7}{1.421664} + \frac{-1}{1.693737088} + \frac{9}{2.01797351296} + \frac{15}{2.40449389128}$$
$$= -20 + 5.035 + 4.924 + (-0.591) + 4.458 + 6.239$$
$$= -20 + 20.065 = 0.065$$

Since the NPV is positive but close to zero, we continue refining our guess slightly higher until we zero in on the IRR. With iterative refinement, we would zero in on an IRR of approximately 19.32%.

By interpolation Method

NPV at 20% = -0.351

NPV at 19% = 0.172

$$\text{IRR} = \text{Lower rate} + \frac{\text{NPV at lower rate x (Higher rate-lower rate)}}{(\text{NPV at lower rate} - \text{NPV at higher rate})}$$

$$\text{IRR} = 19 + \frac{0.172 \text{ x } (20-19)}{(0.172 - (-0.351)}$$

$$\text{IRR} = 19 + \frac{0.172}{0.523}$$

$$\text{IRR} = 19 + 0.32 = 19.32\%$$

L3	a) A cement plant is planning for ISO 50001 certification. Write a goal, objective and target for meeting the requirements of energy management system b) For an energy efficiency project, define (i) net operating cash inflows (ii) Economic life (iii) Salvage value c) Compare between NPV and IRR

Solution:

a) Book 1, Page 157
b) Book 1, Page 173
c) Book 1, Page 172

L4

a)

You are part of the team responsible for evaluating the total energy consumption of a manufacturing plant. This plant operates around the clock and has substantial heating and cooling needs due to its production processes. It sources energy from electricity purchased from the grid, furnace oil for thermic fluid heaters, coal for steam boilers, High-Speed Diesel for diesel generators, and Liquefied Petroleum Gas for ovens. To determine if the plant qualifies as a designated consumer under EC Act, list down the data required for assessing the MTOe.

b) An energy manager in a factory has gathered following data to arrive at the plant energy performance. Reference year (2022) energy use was 20 million kcal and production factor (PF) for the current year (2023) is 0.9. While the current year's energy use is 19 million kcal. What is the plant energy performance of the factory for the year 2023? State the inference.

Solution:

a)

Energy Source	Description	Unit of Measurement
Electricity	Purchased from grid	kWh
Furnace Oil	Used for thermic fluid heater	Liters
Coal	Used for steam boiler	Metric tons
HSD (High-Speed Diesel)	Used for diesel generators	Liters
LPG (Liquefied Petroleum Gas)	Used for ovens	Kilograms

b)

Given:

Reference year energy use (2022) = 20 million kcal
Production factor (PF) for the current year (2023) = 0.9

Reference year energy equivalent = Reference year energy use × Production factor
=20 million kcal X 0.9
=18 million kcal

To calculate the plant energy performance for the year 2023:

$$\text{Plant Energy Performance} = \frac{\text{Reference Year Equivalent} - \text{Current Years Energy use}}{\text{Reference Year Equivalent}} \times 100$$

$$= \frac{18-19}{18} \times 100 = -5.56\%$$

Inference:

The plant energy performance has decreased by 5.56% in 2023 compared to the reference year energy use in 2022. This indicates that the factory's energy efficiency has worsened, as it consumed 5.56% more energy than expected based on the production factor.

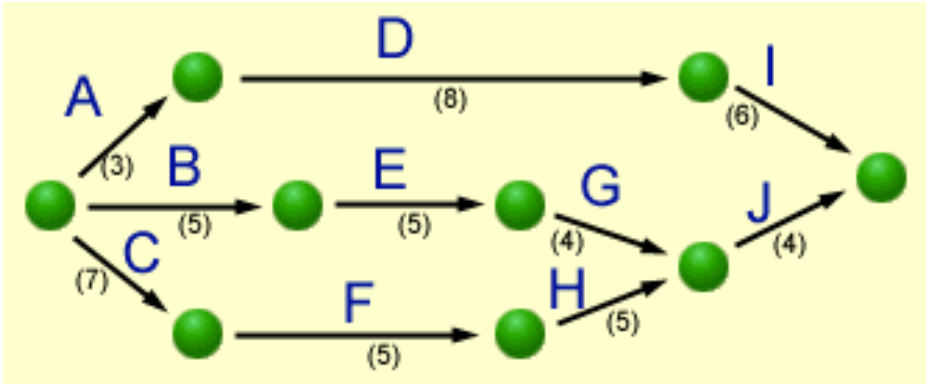
L5

a) Draw PERT chart for the following task, dependency and duration. 5 Marks
b) Find the critical path 2 Marks
c) Calculate expected project duration 3 Marks

Task	Predecessors Tasks (Dependencies)	Expected Time as Calculated (Weeks)
A	-	3
B	-	5
C	-	7
D	A	8
E	B	5
F	C	5
G	E	4
H	F	5
I	D	6
J	G - H	4

Solution:

a)



b) The critical path is through activities C, F, H, J

c) The expected project duration is 21 weeks (7+5+5+4)

L6

An evaporator is to be fed with 5000 kg/hr of a solution having 0.5 % solids. The feed is at 38°C, and is to be concentrated to 1% solids. Steam is entering at a total enthalpy of 640 kcal/kg and the condensate leaves at 100 °C. Enthalpies of feed are 38.1 kCal/kg, product solution is 100.8 kCal/kg and that of the vapour is 640 kCal/kg. Find the mass of vapour formed per hour and the mass of steam used per hour.

Solution:

	Mass of vapour Feed= 5000 kg/hr @ 0.5 solids Solids = 5000 x 0.5/100 = 25 kg/hr $Mass_{out}$ x 1/100 = 25 $Mass_{out}$ = 2500 kg/hr Vapour formed = 5000-2500 = 2500 kg/hr Thick liquor = 2500 kg/hr **Steam Consumption** Enthalpy of Feed = 5000 x 38.1 = 190500 kcal Enthalpy of the thick liquor = 100.8 x 2500 = 252000 kcal Enthalpy of vapour = 640 x 2500 = 16,00,000 kcal **Heat Balance** Heat input by steam + Heat in Feed = Heat out in vapour + Heat out in thick liquor [M x (640-100) + 38.1 x 5000] = 1600000 + 252000) M x 540 = 1661500 M= 3076.8 kg/hr

_____END_____