NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY MANAGERS & ENERGY AUDITORS
Question Papers & Model solutions to the Question Papers

PAPER – 1: General Aspects of Energy Management & Energy Audit

Date: 28.05.2005 Timings: 0930-1230 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- *Please check that this question paper contains **7** printed pages*
- *Please check that this question paper contains **65** 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: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Put a (√) tick mark in the appropriate box in the answer book

1.	Primary energy sources are, a) electricity **b) converted into secondary energy sources** c) used in diesel generator sets d) LPG, petrol & diesel
2.	Eighty percent of the worlds' population lives in developing countries and consumes approximately …… of the world's total energy consumption a) 80 % b) 60 % **c) 40 %** d) 20 %
3.	Energy consumption per unit GDP is called a) energy ratio **b) energy intensity** c) per capita consumption d) all of the above
4.	Identify the wrong statement for a measure to reduce energy costs in a furnace by substitution of a fuel. a) fuel switching may improve energy efficiency. b) fuel switching may reduce energy efficiency. c) fuel switching may reduce energy costs. **d) fuel switching always reduces energy consumption.**
5.	The Energy Conservation Act 2001 does not require designated consumers to a) appoint/designate certified energy manager b) conduct an energy audit through an accredited energy auditor c) comply with energy consumption norms & standards **d) invest in all energy conservation measures**

6.	An energy audit as defined in the Energy Conservation Act 2001 includes a) verification, monitoring and analysis of use of energy b) submission of technical report with recommendations c) action plan to reduce energy consumption **d) all of the above**
7.	An example of stored mechanical energy is a) water in a reservoir **b) an arrow in a stretched bow** c) an air-borne aeroplane d) you on top of a mountain
8.	Mega Volt Ampere (MVA) in a three phase electrical circuit could be written as a) $\frac{\text{Voltage x Ampere}}{1000}$ b) $\frac{\text{Voltage x Ampere}}{1{,}000{,}000}$ c) Voltage x Ampere x1,000 **d) none of the above**
9.	When the current lags the voltage in an alternating current system, it is caused mainly due to a) resistive load b) capacitive load **c) inductive load** d) none of the above
10.	The phase change from solid state to a liquid state is called a) fission b) enthalpy c) latent heat **d) fusion**
11.	The "superheat" of steam is expressed in a technical report as **a) degrees Centigrade above saturation temperature** b) critical temperature of the steam c) the temperature of the steam d) none of the above
12.	The rate of energy transfer from a higher temperature to a lower temperature is measured in a) kCal **b) Watt** c) Watts per Second d) none of the above.
13.	The electrical power unit GigaWatt (GW) may be written as a) 1,000,000,000 MW **b) 1,000 x MW** c) 1,000 x kW d) 1,000,000 x W
14.	CO_2 measurement with a Fyrite kit is based on a) weight basis (dry) **b) volume basis (dry)** c) weight basis (wet) d) volume basis (wet)
15.	A good coal has a Gross Calorific Value of 26,000 MJ/ton. Expressed in kCal/kg the Gross Calorific Value is a) 621000 b) 62100 **c) 6210** d) 621
16.	The annual energy consumption of a plant in the reference year 2003/2004 was 1 Lakh GJ. In the next year 2004/2005 it was 1.1 Lakh GJ. The plant energy performance (PEP), assuming no change in product mix and output quantity in ____ **a) –10%** b) 10% c) –9.1% d) none of the above
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26.	Fill in the missing word. An energy policy provides the _____ for setting performance goal and integrating energy management into an organization's culture. a) budget b) delivery mechanism c) action plan **d) foundation**
27.	Which one is not a step in energy action planning a) make commitments b) implement action plan c) set goals **d) report results to designated agency of the state**
28.	PERT/ CPM provides the following benefits a) graphical view of the project b) shows activities which are critical to maintaining the schedule c) predicts the time required to complete the project **d) all the above**
29.	What does normalization of data mean? a) comparing data with respect to performance of a specific year **b) removing the impact of various factors on data** c) indexing performance of process data d) benchmarking performance

30.	Benchmarking helps to a) track performance change over time b) compare with best/average performance **c) both a & b** d) none of the above
31.	One of the basic indicators of financial investment appraisal is a) risk assessment b) trending of fuel costs c) interest rate **d) simple payback**
32.	What does the concept of time value of money imply a) present value of money b) future value of money c) discounting of cash flows **d) all of the above**
33.	Return on Investment (ROI) as a fraction means a) initial investment / annual return b) annual cost / cost of capital **c) annual net cash flow / capital cost** d) none of the above.
34.	The net present value (NPV) is **a) equal to the sum of the present values of all cash flows** b) equal to the sum of returns c) equal to the sum of all cash flows d) none of the above
35.	The Internal Rate of Return (IRR), of an investment is calculated by a) selecting a discount rate so that NPV = 0 b) equating total discounted costs with total discounted benefits c) making sure the benefit / cost ratio equals unity **d) all of the above**
36.	Which one is not a macro factor in a sensitivity analysis? a) change in interest rates b) technology changes **c) cost of debt** d) change in tax rates
37.	Which service is normally not part of an ESCO contract? a) financing of measures b) engineering analysis and design c) project development and supervision **d) obtaining operation permits**
38.	In Project Management, what does the 80/20 Rule say? a) 20% is trivial and 80% is vital work **b) 20% of work consumes 80% of time and resources** c) the first 20% of work consumes 80% of your time and resources d) none of the above.
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41.	Critical path in a CPM network diagram **a) is the longest path in a network** b) is the shortest path in a network c) where all activities of long duration fall d) none of the above.
42.	PERT stands for _____ a) Project Evaluation Research Technique **b) Programme Evaluation & Review Technique** c) Power & Energy Reforms Techniques d) none of the above
43.	Drawing a Gantt chart does not require **a) to know cost of the activities** b) duration of activity c) to know beginning of the activities d) to know the interdependency of the tasks
44.	Pie chart of the fuel mix on energy consumption represents a) percentage share of fuels based on costs b) percentage share of fuels based on energy bill c) percentage share of fuels based on volume content **d) percentage share of fuels based on common unit of energy**
45.	In an CUSUM chart, if the graph is horizontal for two consecutive periods then a) actual and calculated energy consumption are the same b) actual energy consumption is reduced c) specific energy consumption is the same **d) each one of the above may be true**
46.	In an industry the electricity consumed for a period is 1,00,000 kWh. The production in this period is 10,000 tons with a variable energy consumption of 7 kWh/ton. The fixed kWh consumption of the plant is **a) 30000** b) 23000 c) 7000 d) 10000
47.	Which is a greenhouse gas a) Sulfur Dioxide b) Nitrogen **c) Nitrous Oxide** d) none of the above
48.	Which country was the latest to recently ratify the Kyoto Protocol a) USA b) Australia **c) Russia** d) Germany
49.	One of the flexible instrument as stated in the Kyoto Protocol is a) CO_2 adaptation **b) Clean Development Mechanism (CDM)** c) CO_2 sequestration mechanism d) none of the above
50.	Methane traps about ____ times more heat than Carbon Dioxide a) 7 b) 14 **c) 21** d) 28

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

Section - II: SHORT DESCRIPTIVE QUESTIONS Marks: 10 x 5 = 50

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

S-1 (i) State two obvious measures, which may reduce the ratio of energy consumption to gross domestic product (GDP) in the Indian economy.
(ii) What is roughly the ratio under present conditions?

(i) All energy efficiency measures and all national programmes to promote low energy-intensive sectors of the Indian economy will obviously lower energy intensity.
(ii) The present ratio is cited as 1.5, based on Book 1. Any answer between 0.7 and 1.5 should be seen as correct.

S-2 Define Dew Point.

It is the temperature at which condensation of water vapour from the air begins, as the temperature of the air-water vapour mixture falls.

S-3 State the key elements of an energy audit as defined in the Energy Conservation Act 2001.

There are six key elements mentioned in the original text of the Act.

"Energy audit" means the (i) verification, (ii) monitoring and analysis of use of energy, including (iii) submission of technical report, (iv) containing recommendations for improving energy efficiency with, (v) cost benefit analysis and an, (vi) action plan to reduce energy consumption.

S-4 During an air pollution monitoring study, the inlet gas stream to a bag filter was 200,000 m^3 per hour. The outlet gas stream from the bag filter was a little bit higher at 210,000 m^3 per hour. Dust load at the inlet was 6 gram/ m^3, and at the outlet 0.1 gram/ m^3. How much dust in kg/hour was collected in the bag filter bin?

Dust (gas in) = dust (in gas out) + dust (in bin)
200,000 x 6 = 210,000 x 0.1 + x and it follows

x = 1,179,000 gram/hour = 1,179 kg/hour.

S-5 List 5 positive forces of a force field analysis in support of the goal: "Reduce energy consumption per unit production".

(i) high price of energy
(ii) energy efficient technology available
(iii) top management commitment to energy conservation
(iv) energy is high component of product cost
(v) incentives for energy conservation available

S-6 Define the Internal Rate of Return (IRR) and write it's equation.

(i) The internal rate of return is the discount rate, d, at which the Net Present Value, NPV, becomes zero.

(ii) $$\text{or NPV} = \frac{C_0}{(1+d)^0} + \frac{C_1}{(1+d)^1} + \ldots \frac{C_n}{(1+d)^n} = 0$$

with C_i = Cash flow occurring in the year i,
n = life of project in years;
d = discount rate as a fraction and not in %

S-7 List 5 steps in a PERT planning process

(i) identify specific activities and milestones.
(ii) determine the proper sequence of the activities
(iii) construct a network diagram.
(iv) estimate the time required for each activity.
(v) determine the critical path
(vi) update the PERT chart as the project progresses.

S-8 A company consumes 1.3 x 10^5 kWh of electricity and 11.18 x 10^7 kCal of furnace oil per month. Draw the pie chart of percentage share of fuels based on consumption in kCal. (1 kWh = 860 kcal)

The pie chart is split in half (50% oil and 50% electricity) because 1 kWh = 860 kCal and therefore 130,000 x 860 = 11.18 x 10^7 kCal

S-9 The company "Save Electricity the Smart Way" sells a gadget that lowers voltage of your electric water storage heater by 20% and saves electricity by 20%. The heater is rated 2 kW at 230 V. Do you agree with the claim of the company? Support your opinion.

The answer is "No electricity is saved." (ii) There are no calculations necessary. The given information about the water is not needed. Due to the lower voltage the kW load will go down. Therefore the process to heat the water will take longer based on the energy balance. Since the gadget to lower the voltage consumes itself electricity the electricity consumption in fact goes slightly up on paper.

S-10 (i) Why is the Ozone layer important to plant, animal and human life on earth?
(ii) which substances are destroying it, and
(iii) by which process?

(i) Ozone (O_3) is a filter for harmful Ultra Violet -B rays.
(ii) Chlorine and bromine compounds, such as CFC's, and HCFC's are destroying Ozone.
(iii) Ozone is highly reactive and can be easily broken down. If UV rays hit CFC's and HCFC's the chlorine (Cl) atom is separated from the carbon atom and this Cl atom reacts with Ozone, breaking it apart.

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

Section - III: LONG DESCRIPTIVE QUESTIONS Marks: 5 x 10 = 50

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

L-1 The following table shows the import bill of fossil fuels in million metric tonnes (MMT) and its cost in Crores Rupees over the last eight years.

(i) calculate the average annual percentage increase of fossil fuel imports
(ii) calculate the average annual percentage increase of the import bill
(iii) calculate the average costs for the last eight years, in Rs. Per metric ton of imported fossil fuels.

Import bill of fossil fuels		
Year	**Quantity (MMT)**	**Value (Rs.Crore)**
1996-97	33.90	18,337
1997-98	34.49	15,872
1998-99	39.81	19,907
1999-00	57.80	40,028
2000-01	74.10	65,932
2001-02	84.90	80,116
2002-03	90.00	85,042
2003-04	95.00	93,159

There are seven years to consider

(i) 95 / 33.90 = 2.80236 folded increase over 7 years. It follows to solve the equation $(1.\ x)^7 = 2.80236$ by introducing the exponent 1/7 of each side we get $1.x = 2.80236^{1/7}$ or 1.x = 1.15859 or 15.86%. By trial and error one should get close to the result as well. Any number between 15.5% and 16% should count as correct

(ii) 93,159 / 18,337 = 5.0804 folded increase over 7 year. Similar to (i) it follows 26.14%. Any answer between 26.0% and 26.3% should count as correct.

(iii) The sum of all imports is 510 Million metric tons over this time period. The value is Rs 418,393 Crore. Consequently average costs are calculated as (418,393 x 10,000,000)/510,000,000 = 8,203.78 Rs per metric ton.

L-2 An energy manager or energy auditor is trying to establish the power factor of a 15 HP induction motor. The instrument to measure electric parameters displays the three numbers 5 kW and 2 kVAr and PF = 92.8%. Do you fully agree with the instrument display and its correctness?

Rectangular triangle and Pythagoras yields $(kVA)^2 = (kW)^2 + (kVAr)^2$. Furthermore PF = kW/kVA, and consequently
$kVA = \sqrt{(kVAr)^2 + (kW)^2} = \sqrt{(2)^2 + (5)^2} = 5.38516$ and PF = 5/5.38516 = 0.928

This calculation agrees with the display of 92.8%.

However it is unlikely that a 10 kW motor operating at 50% load will ever achieve PF = 0.928. Consequently something is suspicious with the instrument. Therefore the answer is NO, because it is also unlikely that a 15 HP induction motor is compensated in such a way that this power factor is achieved at 50% load.

L-3 Fuel substitution from a high cost fuel to a low cost fuel in boilers is common to reduce energy bill. For the following situations calculate:

(i) annual reduction in energy costs in Crore Rs.
(ii) annual change in energy consumption in %. (Calorific value of fuels not required for calculations)

Before substitution:

Steam output	=	6 tons/hour
Fuel consumption	=	1 ton oil per 13 tons of steam.
Operating hours	=	6400 / Year
Fuel costs	=	Rs.13,000 /ton of oil
Boiler thermal efficiency (yearly average)	=	82%

After Substitution:

Steam output	=	6 tons/hour
Fuel consumption	=	3 tons of waste wood per 13 tons of steam
Fuel costs	=	Rs.2,000 / ton of waste wood
Boiler thermal efficiency (yearly average)	=	74%

Oil consumption before substitution was 6 x 6400/13 = 2,953.85 tons/y.
The annual oil costs were 2,953.85 x 13,000= 38,400,050 = Rs 3.84 Crore

Wood consumption after substitution is 6 x 6400x 3/13 =8,861.54 tons/y
The annual waste wood costs are 8,861.54 x 2,000 = 1.77 Crore Rs.
(i) The annual reduction in fuel costs is Rs 2.07 Crore.

(ii) More energy is used because the boiler efficiency drops
the change is 100 x (74-82)/74 = 10.8% more energy

L-4 A company invests Rs.10 lakhs and completes an energy efficiency project at the beginning of year 1. The firm is investing its own money and expects an internal rate of return, IRR, of at least 26% on constant positive annual net cash flow of Rs.2 lakhs, over a period of 10 years, starting with year 1.

(i) Will the project meet the firm's expectations?
(ii) What is the IRR of this measure?

Solution

(i) Use the NPV formula with d = 0.26 and check to what extent NPV > 0 at n = 10 years.

$$\text{NPV} = -1{,}000{,}000 + \frac{200{,}000}{1.26^1} + \frac{200{,}000}{(1.26)^2} + \ldots\ldots \frac{200{,}000}{(1.26)^{10}} =$$

= - 1,000,000 + 158,730 + 125,976 + 99,981 + 79,350 + 62,976 + 49,981 + 39,668 + 31,482 + 24,986 + 19,830 = MINUS 307,040

Since NPV is negative at 26%, project will not meet the firm's expectations, because this means that the factor of 1.26 must be selected smaller in order to have NPV = 0 (7 marks)

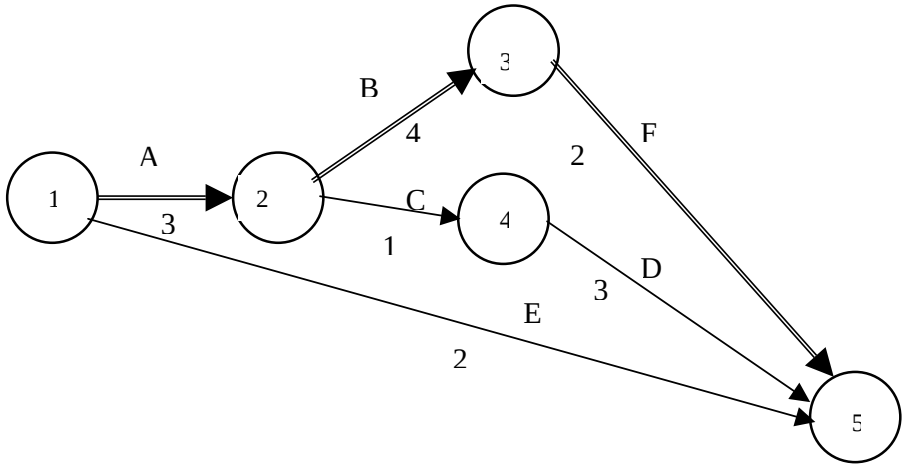
(ii) The IRR is 15.1%. Any result between 14.5 and 15.5 is valid

L-5 (i) Construct a CPM diagram for the data given below
(ii) Identify the critical path. Also compute the earliest start, earliest finish, latest start & latest finish of all activities

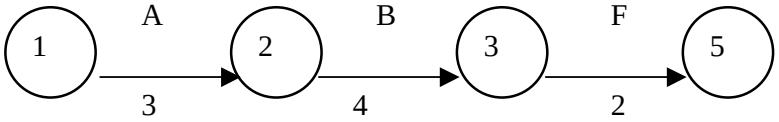
Activity	Precedent	Time, weeks
A	Start	3
B	A	4
C	A	1
D	C	3
E	Start	2
F	B	2
Finish	D, E, F	--

Solution

(i)



ii) critical Path



Total time on critical path: 9 weeks

Early start (ES), Early Finish (EF), Latest start (LS), Latest finish (LF)

S.no	Activity	Duration	ES	EF	LS	LF
1	A	3	0	3	0	3
2	B	4	3	7	3	7
3	C	1	3	4	5	6
4	D	3	4	7	6	9
5	E	2	0	2	7	9
6	F	2	7	9	7	9

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38.	Which one is not a step in energy action planning a) make commitment b) implement action plan c) set goals d) **report result to designated agency**
39.	PERT/ CPM provides the following benefits a) graphical view of the project b) shows activities which are critical to maintaining the schedule c) predicts the time required to complete the project **d) all the above**

40.	What does normalization of data mean? a) comparing data with respect to performance of a specific year **b) removing the impact of various factors on data** c) indexing performance of process on data d) benchmarking performance
41.	Primary energy sources are, a) electricity **b) converted into secondary energy sources** c) used in diesel generator sets d) LPG, petrol & diesel
42.	Eighty percent of the worlds' population lives in developing countries and consumes approximately …….. of the world's total energy consumption a) 80 % b) 60 % **c) 40 %** d) 20 %
43.	Energy consumption per unit of GDP is called a) energy ratio **b) energy intensity** c) per capita consumption d) all of the above
44.	Identify the wrong statement for a measure to reduce energy costs in a furnace by substitution of a fuel. a) fuel switching may improve energy efficiency b) fuel switching may reduce energy efficiency. c) fuel switching may reduce energy costs. **d) fuel switching always reduces energy consumption.**
45.	The Energy Conservation Act 2001 does not require all notified designated consumers to a) appoint/designate certified energy manager b) conduct an energy audit through an accredited energy auditor c) comply with energy consumption norms & standards **d) invest in all energy conservation measures**
46.	An energy audit as defined in the Energy Conservation Act 2001 includes a) verification, monitoring and analysis of use of energy b) submission of technical report with recommendations c) action plan to reduce energy consumption **d) all of the above**
47.	An example of stored mechanical energy is a) water in a reservoir **b) an arrow in a stretched bow** c) an air-borne aeroplane d) you on top of a mountain
48.	Mega Volt Ampere (MVA) in a three phase electrical circuit could be written as a) $\frac{\text{Voltage x Ampere}}{1000}$ b) $\frac{\text{Voltage x Ampere}}{1{,}000{,}000}$ c) Voltage x Ampere x1,000 **d) none of the above**
49.	When the current lags the voltage in an alternating current system, it is mainly due to a) resistive load b) capacitive load **c) inductive load** d) none of the above
50.	The phase change from solid state to a liquid state is called a) fission b) enthalpy c) latent heat **d) fusion**

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

Section - II: SHORT DESCRIPTIVE QUESTIONS Marks: 10 x 5 = 50

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

S-1 List 5 negative forces of a force field analysis, which are a barrier to the objective "reduce energy consumption per unit production"

(i) Low price of energy
(ii) Technology not available
(iii) Top management not committed
(iv) Energy is low component of product cost
(v) No incentives for energy conservation available
(vi) Firm makes enough profit
(vii) Lack of awareness throughout company
(viii) Absence of corporate energy policy
(ix) Insufficient financial resources to find measure.

S-2 Define Latent Heat

It is the (i) change in (ii) heat (energy) content of a substance, when its (iii) physical state is changed (iv) without change in (v) temperature.

S-3 Distinguish between Gross Colorific Value (GCV) and Net Calorific Value (NCV) of a fuel.

The difference between GCV and NCV is the (i) heat of vaporization of the water that is either (ii) physically present in the fuel as moisture or (iii) formed from the Hydrogen in the fuel during the combustion process. (iv) NCV does not account for the heat of vaporization and is therefore always smaller than GCV if a fuel contains hydrogen or moisture.

S-4 During an air pollution monitoring study, the inlet gas stream to a bag filter was 100,000 m^3 per hour. The outlet gas stream from the bag filter was a little bit higher at 120,000 m^3 per hour. Dust load at the inlet was 5 gram/ m^3, and at the outlet 0.2 gram/ m^3. How much dust was in kg/hour was collected in the bag filter bin?

Dust (gas in) = dust (in gas out) + dust (in bin)
100,000 x 5 = 120,000 x 0.2 + x and it follows

x = 476,000 gram/hour = 476 kg/hour.

S-5 (i) State two obvious measures which may reduce the ratio of energy consumption to gross domestic product (GDP) in the Indian economy.
(ii) What is roughly the ratio under present conditions?

(i) All energy efficiency measures and all national programmes to promote less energy-intensive sectors of the Indian economy will obviously lower energy intensity.
(ii) The present ratio is 1.5 based on Book 1 and any answer between 0.7 and 1.5 should be seen as correct.

S-6 List 5 sources of greenhouse gases which are either naturally occurring or are caused by human activities.

(i) CO_2 (Carbon Dioxide), (ii) CH_4 (Methane), (iii) NO_x (Nitrous Oxides), (iv) $H_2O(g)$ (Water in vapor form), (v) HFCs (Hydro Fluor Carbons), (vii) SF_6 (Sulfur Hexafluoride), (viii) PFCs (Pero Fluoro Carbons)

(OR)

Burning of fossil fuels, deforestation, agriculture, industry, transport.

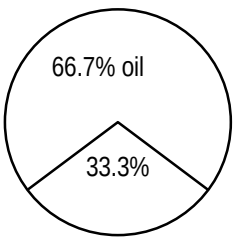
S-7 The company "Save Electricity the Smart Way" sells you a gadget that lowers voltage of your electric water storage heater by 10% and saves electricity by 10%. The heater is rated at 2 kW at 230 V. Do you agree with the claim of the company? Support your opinion.

The answer is "No electricity is saved." There are no calculations necessary. The given information about the water is not needed. Due to the lower voltage the kW load will go down. Therefore the process to heat the water will take longer based on the energy balance. Since the gadget to lower the voltage consumes itself electricity the electricity consumption in fact goes slightly up on paper.

S-8 A company consumes 5,000 tons of furnace oil per year (GCV =10,200 kCal/kg), as well as 29,651 MWh of electricity per year. Draw the pie-chart of percentage share of fuels based on consumption in kCal (1kWh = 860 kcal)

5,000 tonnes x 10,200 kCal x1000 = 5.10×10^{10} kCal
29,651 MWh = 29,651,000 kWh
= 29,651,000 x 860 kCal
= 2.55×10^{10} kCal

Total consumption 5.10 + 2.55 = 7.65×10^{10} of which 2/3 (66.7%) is oil and 1/3 (33.3%) is electricity.



Electricity

S-9 Define the Internal Rate of Return (IRR) and write it's equation.

(i) The Internal Rate of Return is the discount rate d at which the net present value NPV becomes zero.

(ii) $$\text{or, NPV} = \frac{C_0}{(1+d)^0} + \frac{C_1}{(1+d)^1} + \ldots \frac{C_n}{(1+d)^n} = 0$$

with C_i = Cash flow occurring in the year i,
n = life of project in years;
d = discount rate as a fraction and not in %

S-10 State the key elements of an energy audit as defined in the Energy Conservation Act 2001.

There are six key elements mentioned in the original text of the Act.

"Energy audit" means the (i) verification, (ii) monitoring and analysis of use of energy, including (iii) submission of technical report, (iv) containing recommendations for improving energy efficiency with, (v) cost benefit analysis and an, (vi) action plan to reduce energy consumption.

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

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 5 x 10 = 50**

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

L-1 An energy auditor or an energy manager is trying to establish the power factor of a 7.5 HP induction motor. The instrument to measure electric parameters displays the three numbers 2.5 kW and 1 kVAr and PF = 92.9%. Do you fully agree with the instrument display and its correctness?

Right angle triangle and Pythagoras yields $(kVA)^2 = (kW)^2 + (kVAr)^2$. Furthermore PF = kW/kVA, and consequently
$kVA = \sqrt{(kVAr)^2 + (kW)^2} = \sqrt{(1)^2 + (2.5)^2} = 2.69$ and PF = 2.5/2.69 = 0.928

This calculation agrees with the display of 92.9%

However it is unlikely that a 5.5 kW motor operating at 50% load will ever achieve PF = 0.929. Consequently something is suspicious with the instrument. Therefore the answer is NO, because it is also unlikely that a 7.5 HP induction motor is compensated in such a way that this power factor is achieved at 50% load.

L-2 The following table shows the import bill of fossil fuels in million tonnes and its cost in Crores Rupees over the last eight years.

(i) calculate the average annual percentage increase of fossil fuel imports
(ii) calculate the average annual percentage increase of the import bill
(iii) calculate the average costs for the last eight years, in Rs. Per metric ton of imported fossil fuels.

Import bill of fossil fuels		
Year	**Quantity (MMT)**	**Value (Rs.Crore)**
1996-97	33.90	18,337
1997-98	34.49	15,872
1998-99	39.81	19,907
1999-00	57.80	40,028
2000-01	74.10	65,932
2001-02	84.90	80,116
2002-03	90.00	85,042
2003-04	95.00	93,159

There are seven years to consider

(i) **95 / 33.90 = 2.80236 folded increase over 7 years. It follows to solve the equation $(1.\ x)^7 = 2.80236$ by introducing the exponent 1/7 of each side we get $1.x = 2.80236^{1/7}$ or 1.x = 1.15859 or 15.86%. By trial and error one should get close to the result as well. Any number between 15.5% and 16% should count as correct**

Give 2 marks if the average is calculated as the arithmetic average by summation the increase over each year. Result is 16.67%

(ii) **93,159 / 18,337 = 5.0804 folded increase over 7 year. Similar to (i) it follows 26.14%. Any answer between 26.0% and 26.3% should count as correct.**

Give 2 marks if the arithmetic average is formed out of the sum of yearly increases. The result is 29.37%

(iii) **The sum of all imports is 510 Million metric tons over this time period. The value is Rs 418,393 Crore. Consequently average costs are calculated as (418,393 x 10,000,000)/510,000,000 = 8,203.78 Rs per metric ton.**

L-3 Fuel substitution from a high cost fuel to a low cost fuel is common to reduce energy bill. For the following situations calculate:

(i) annual reduction in energy costs in Crore Rs .
(ii) annual change in energy consumption in %. (Calorific value of fuels not required for calculations)

Before substitution:

Steam output	=	5 tons/hour
Fuel consumption	=	1 ton oil per 13 tons of steam.
Operating hours	=	6000 / Year
Fuel costs	=	Rs.13,000 /ton of oil
Boiler thermal efficiency (yearly average)=		84%

After Substitution:

Steam output	=	5 tons/hour
Fuel consumption	=	2.5 tons of shells per 13 tons of steam
Fuel costs	=	Rs.2,800 / ton of shells
Boiler thermal efficiency (yearly average)		= 72%

Oil consumption before substitution was 5 x 6000/13 = 2,307.69 tons/y.
The annual oil costs were 2,307.69 x 13,000= 29,999,970 = Rs 3 Crore

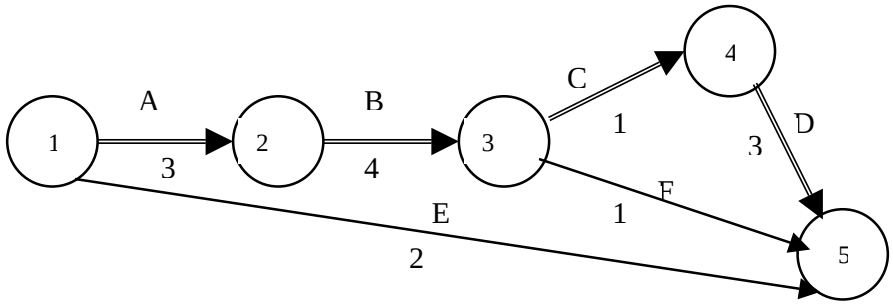
Shell consumption after substitution is 5 x 6000x 2.5/13 = 5,769.23 tons/y
The annual shell costs are 5,769.23 x 2,800 = Rs 1.615 Crore
(i) The annual reduction in fuel costs is Rs 1.385 Crore.

(ii) More energy is used because the boiler efficiency drops
the change is 100 x (72-84)/72 = 16.7% more energy

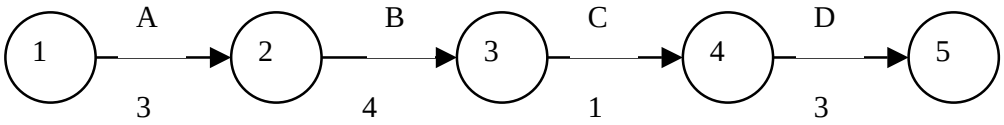
L-4 (i) Construct a CPM diagram for the example below
(ii) Identify the critical path. Also compute the earliest start, earliest finish, latest start & latest finish of all activities?

Activity	Precedent	Time, weeks
A	Start	3
B	A	4
C	B	1
D	C	3
E	Start	2
F	B	1
Finish	D, E, F	--

(i)



ii) Critical Path:



Total time on critical path: 11 weeks

Early start (ES), Early Finish (EF), Latest start (LS), Latest finish (LF)

S.no	Activity	Duration	ES	EF	LS	LF
1	A	3	0	3	0	3
2	B	4	3	7	3	7
3	C	1	7	8	7	8
4	D	3	8	11	8	11
5	E	2	0	2	9	11
6	F	1	7	8	10	11

L-5 A company invests Rs.6 lakhs and completes an energy efficiency project at the beginning of year 1. The firm is investing its own money and expects an internal rate of return, IRR, of at least 20% on constant positive annual net cash flow of Rs. 1 lakh, over a period of 10 years, starting with year 1.

(i) Will the project meet the firm's expectations?
(ii) What is the IRR of this measure?

Solution

(i) Use the NPV formula with d = 0.20 and check to what extent NPV > 0 at n = 10 years.

(ii) NPV = - 600,000 + 100,000 + 100,000 + …… 100,000 =

1.20^{1} $(1.20)^{2}$ $(1.20)^{10}$

= - 600,000 + 83,333 + 69,444 + 57,870 + 48,225 + 40,188 + 33,490 + 27,908 + 23,257 + 19,381 + 16,151 = Minus 180,753

Since NPV is negative at 20%, the expectation of the project will not met the firm's expectations, because this means that the factor of 0.20 must be selected smaller in order to have NPV = 0

The IRR is 10.56%. Any result between 10.2% and 10.7 is valid

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

NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY MANAGERS & ENERGY AUDITORS
Question Papers & Model solutions to the Question Papers

PAPER – 2: Energy Efficiency in Thermal Utilities

Date: 28.05.2004 Timings: 1400-1700 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- *Please check that this question paper contains **7** printed pages*
- *Please check that this question paper contains **65** 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: OBJECTIVE TYPE

Marks: 50 x 1 = 50

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Put a (√) tick mark in the appropriate box in the answer book

1.	Specific heat in kCal/kg -^{0}C of fuel oil is in the range of a) 0.15 – 0.20 **b) 0.22 – 0.28** c) 0.29 – 0.32 d) none of the above
2.	Grade B Indian coal has a energy content range (in kcal/kg) of a) 3360-4200 b) 4200-4900 c) 4940-5600 **d) 5600-6200**
3.	Which is the common coal firing system used in Indian thermal power plants? **a) pulverized coal firing** b) stoker firing c) fluidized bed d) pressurized bed
4.	Which of the following fuel requires maximum air for stochiometric combustion? a) Butane b) Propane **c) Hydrogen** d) Coal
5.	Stochiometric air required for combustion of Bagasse is about a) 13.7 **b) 3.2** c) 6 d) 18
6.	Which fuel releases the most energy per kg on complete combustion a) Carbon b) Sulphur c) Nitrogen **d) Hydrogen**
7.	How many kg of CO_2 are produced in complete combustion of 16 kg of Methane? a) 42 **b) 44** c) 16 d) none of the above

8.	In flue gas the theoretical CO_2 is 15.5% and measured CO_2 is 11% by volume. The percentage of excess air will be **a) 40.9%** b) 38.7 % c) 240.9 % d) 140.9 %
9.	Evaporation ratio (steam to fuel ratio) of an oil fired efficient boiler is in the range of a) 5 - 6 **b) 13 – 14** c) 1 - 3 d) 7 – 9
10.	A rise in conductivity of boiler feed water indicates a) drop in the total dissolved solids in boiler water b) more steam generation c) greater purity of feed water **d) rise in the total dissolved solids in boiler water**
11.	De-aeration of boiler feed water is referred to as **a) removal of dissolved gases** b) removal of silica from feed-water c) removal of TDS from feed-water d) phosphate treatment of feed-water
12.	Pre-heating of combustion air in an oil fired furnace by 20^0 C will save about ___% of fuel a) 0.3 **b) 1** c) 1.5 d) 0.6
13.	To drain condensate from main steam line, the following type of trap is a suitable trap. a) float b) bimetallic **c) thermodynamic** d) none of the above
14.	Increase in stack gas temperature of 22^0 C due to tube fouling or other causes will increase oil consumption in an oil fired boiler by about. **a) 1%** b) 2% c) 3% d) 4%
15.	Water hammer in a steam system is caused by **a) collected condensate hitting obstructions** b) leaking pipe joints c) slow moving steam d) continuous slope in direction of flow
16.	Which data is not required to calculate boiler efficiency by the indirect method **a) steam flow rate** b) stack gas temperature c) ambient temperature d) energy content of fuel
17.	Latent heat at the critical point of a steam phase diagram is a) infinite b) 540 kCal/kg **c) zero** d) none of the above
18.	Increase of steam pressure has the following effect on steam: **a) steam temperature goes up and enthalpy of evaporation goes down** b) steam temperature and enthalpy of evaporation go down c) steam temperature goes up and enthalpy of evaporation goes up d) specific volume goes down and enthalpy of evaporation goes up
19.	Scale losses in reheating furnaces will increase with a) decrease in excess air b) decrease in furnace temperature **c) increase with excess air** d) are not correlated to temperature

20.	An air film inside a steam pipe, made of steel may be _____ times more resistant to heat transfer than the steam pipe. a) 200 – 1000 **b) 1500 – 3000** c) 4000 – 8000 d) 8000 – 16000
21.	The best steam for indirect heating in most industrial process is **a) as dry as possible** b) super heated steam c) wet steam d) as wet as possible
22.	Pressure drop through a steam pipe is inversely proportional to a) diameter b) square of diameter **c) fifth power of diameter** d) cube of diameter
23.	In an oil fired burner, the excess air level _____ towards the highest turndown ratio for efficient combustion. a) decreases **b) increases** c) not affected d) none of the above
24.	What is the most effective way to avoid ambient air infiltration into a continuous furnace a) close all openings b) increase the chimney height c) operate at about 90% capacity **d) reduce negative pressure inside the furnace**
25.	Black body radiation is a) linear proportional to temperature b) proportional to the fourth power of the temperature of the body **c) proportional to the fourth power of the absolute temperature of the body** d) proportional to the square of the body surface area
26.	Steam at 6 bar has a sensible heat of 159.33 kCal/ kg and latent heat of 498.59 kCal/ kg. If the steam is 95% dry than the total enthalpy is a) 625 kCal/ kg b) 649.95 kCal/ kg c) 553 kCal/ kg **d) 633 kCal/ kg**
27.	In which type of furnace operation is a low mass ceramic fiber insulation most suitable to reduce specific fuel consumption **a) batch type furnace** b) continuous Hoffmann tunnel kiln c) rotary high temperature furnace d) low temperature furnace
28.	Which loss is the highest in a typical re-heating furnace operating at 1300^0 C? **a) flue gas loss** b) wall loss c) necessary opening loss d)cooling water loss
29.	In a batch type furnace the following energy efficiency measure would be the most controversial a) increasing the insulation at the hot temperature side **b) increasing the insulation at the outer surface of the furnace** c) pre-heating the combustion air d) reducing excess air.
30.	Pick the wrong statement. The thermal efficiency of a furnace increases by a) preheating combustion air **b) increasing the excess air flow rate** c) reducing the surface heat loss d) minimizing the CO loss and un-burnt losses

31.	The most economic insulation is the thickness where ….. a) depreciation costs of insulation and energy cost due to losses are the same **b) the sum of energy cost due to losses and insulation depreciation cost is minimum** c) energy losses are minimized d) energy cost due to losses are minimized.
32.	Which of the four refractories has the highest melting point temperature? **a) Lime (CaO)** b) Silica (SiO_2) c) Titania (TiO_2) d) Alumina (Al_2O_3)
33.	The emissivity of refractory material…. a) increases sharply above 1000^0 C b) will be more or less independent of temperature c) will increase with increasing temperature **d) will decrease with increasing temperature**
34.	High emissivity coatings are applied on a) outer surface of furnace b) refrigeration piping **c) inner surface of furnace** d) none of the above
35.	The heat loss rate from a surface is expressed in **a) Watt** b) Watt/m^2 – ^{0}K c) Watt/m^2 – ^{0}C d) Joules
36.	Which statement is incorrect a) higher density refractory has a lower thermal conductivity b) a higher emissivity means higher radiation of heat **c) a higher emissivity means lower absorption of heat** d) a black colored body radiates more than a glossy white colored one.
37.	Fluidized bed combustion takes place in a temperature range of a) 600^0C - 700^0C **b) 850^0C - 950^0C** c) above 1000^0C d) about 500^0C
38.	The low combustion temperatures in fluidized bed combustion boilers results in minimal formation of **a) NO_x** b) NO_x and SO_x c) CO_2 d) CO
39.	SO_x emissions in a FBC boiler fired with high sulfur coal are controlled by adding ____ to the bed a) Magnesia **b) Limestone** c) Sand d) Silica
40.	In circulating fluidized bed combustion boilers most of the heat transfer takes place… a) inside the combustion zone b) bed tubes **c) outside of the combustion zone** d) super heater tubes
41.	In glass industry waste heat is used for power generation. This type of cogeneration is called a) topping cycle **b) bottoming cycle** c) gas turbine cycle d) none of the above.
42.	The unit for heat-to-power ratio of a CHP plant is **a) kW_{th} / kW_e** b) BTU / kW c) kCal / kW d) kWh_{th} / kW_e

43.	Which CHP system has the smallest heat to power ratio with the least flexibility to increase or reduce the ratio? a) back pressure turbine **b) combined cycle** c) extraction condensing steam turbine d) reciprocating engine
44.	Air compressor alone consumes about _____ of the energy generated in a gas turbine a) 20-30% b) 30-40% c) 40-50% **d) 50-60%**
45.	Regenerators utilizing waste heat are widely used in… a) cement industry b) pulp and paper **c) glass melting furnaces** d) aluminium
46.	Heat wheels are mostly used in a situation of…. a) high temperature exhaust gases **b) heat exchange between large masses of air having small temperature differences** c) heat transfer between a liquid and gas d) corrosive gases
47.	A heat pipe can transfer up to ____ times more thermal energy than copper a) 10 b) 20 c) 50 **d) 100**
48.	An economizer raises the boiler feed water by 60^0 C and therefore saves approximately ___ % of fuel. a) 5 **b) 10** c) 15 d) 20
49.	A shell and tube heat exchanger is most suitable if **a) a liquid is heating another liquid** b) a gas is heating another gas c) a gas is heating a liquid d) the hot gas is loaded with dust
50.	The working fluid of a steam thermo-compressor is a) air b) low pressure steam **c) high pressure steam** d) water

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

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 10 x 5 = 50**

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

S-1 (i) State the stochiometric combustion equation for Methane.
(ii) how many kg of Carbon Dioxide are generated by complete combustion of 1 kg of Methane?
(iii) how many kg of water are generated by complete combustion of 1 kg of Methane?

(i) $CH_4 + 2O_2 = CO_2 + 2H_2O$

(ii) 16 kg + 64 kg = 44 kg + 36 kg i.e. 2.75 kg of CO_2 from 1 kg of Methane

(iii) 2.25 kg of water from 1 kg of Methane.

S-2 Assume the stochiometric (theoretical) air to fuel ratio of furnace oil is 14. The burner operates at 20% excess air. Calculate the mass of stack gas generated from combustion of one kg of oil.

Mass of air + mass of fuel = mass of stack gas
1.2 x 14 + 1 = 17.8 kg

S-3 (i) Explain the difference between a water tube and a fire tube boiler.
(ii) In what pressure range have water tube boilers an advantage over fire tube boilers and why?

(i) In a fire tube boiler combustion gases are inside small fire tubes, which are bundled, and the water to be heated is outside. In a water tube boiler the water is flowing inside tube bundles and the combustion gases are flowing around the water tubes. (3 marks)

(ii) At steam pressures of more than 20 bar and larger capacities water tube boilers are preferred, because the thickness of a fire boiler shell would be very thick and heavy to withstand the pressure.

S-4 (i) Explain the meaning of h_f, h_{fg} and h_g in a water and steam system
(ii) Write down the equation for h_g if the steam is wet and contains 4% moisture.

(i) h_f = enthalpy of saturated water
h_{fg} = enthalpy of evaporation of saturated water to saturated steam
h_g = enthalpy of saturated steam

(ii) $h_g = h_f + 0.96\ h_{fg}$

S-5 A furnace output is 5000 kg/hour of billets. Thermal efficiency is claimed to be 25% Specific heat of billet is 0.12 kcal/kg-^oC. Billets enter the furnace at 40^oC and leave at 1200^oC. Calculate the hourly oil consumption in liter if GCV of oil is 9,200 kCal/liter.

(i) Efficiency = heat absorbed in the stock = 0.25
heat in fuel

= 5000 x 0.12 (1200- 40) = 0.25
Liter x 9,200

Liter = 302.6 liter of oil per hour.

S-6 In selection of a refractory which physical, chemical and other properties of a refractory are important?

(i) melting or softening point
(ii) bulk density,
(iii) porosity

(iv) thermal conductivity
(v) creep at high temperature
(vi) capital costs

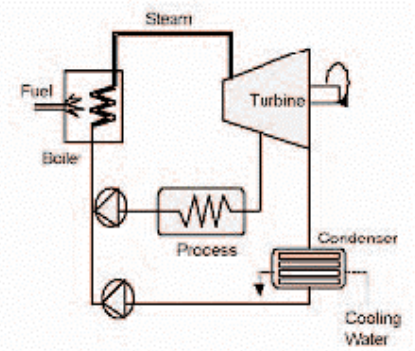
S-7 List advantages of fluidized bed combustion boiler over fixed grate boiler.

(i) efficiency is not so much affected when firing higher ash fuels
(ii) better fuel flexibility
(iii) burns low grade fuels
(iv) burns fines
(v) reduces NO_x formation
(vi) may reduce SO_x formation through additives
(vii) no clinker formation
(viii) no soot blowing
(ix) quicker response to changing demand

S-8 What parameters are analyzed in a proximate analysis of coal?

The elements analyzed in proximate analysis of coal are (i) ash, (ii) moisture, (iii) volatile matter and (iv) fixed carbon content on a (v) percentage weight basis.

S-9 Draw a sketch of an extraction-condensing turbine cogeneration system.



(ii) Extraction-Condensing Turbine

S-10 A firm wants to recover the waste heat in a flue gas stream of 2000 kg/hour. from a furnace. Specific heat of flue gas is 0.25 kcal/kg ^{0}C.

(i) calculate the heat recovered if the heat exchanger has an efficiency of 98% and temperature of flue gas drops from 800^0 C to 250^0 C across the heat exchanger.
(ii) How many liters of water per hour can be heated by 50 ^{0}C from this waste stream?

(i) Heat transferred to water = 2,000 x 0.98 x0.25 x (800 – 250)
= 269,500 kCal / hour

(ii) Solve for "liter" the equation 269,500 = liter x 1 kCal x 50
liter = 5,390 liters / hour.

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

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 5 x 10 = 50**

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

L-1 It is proposed to replace an oil-fired boiler of 10 tons per hour with a coal fired boiler of equivalent capacity. With the help of the data provided find out the following:

(i) the annual oil consumption in tons per year?
(ii) the annual coal consumption in tons per year?
(iii) estimate annual fuel cost savings in Crore rupees
(iv) simple pay back period of the project, assuming the coal fired boiler costs Rs.1.5 Crore and annual repair and maintenance costs is 25% of capital cost.
(v) What additional data could be added for working out a more realistic simple pay back period?

Operation data

Heat content of steam	- 660 kCal/kg.
Feed water inlet temperature	- 60^0 C
Daily operating hours	- 24
Number of days / year	- 300
Efficiency of oil fired boiler	- 82%
Efficiency of coal fired	- 72%
Cost of oil	- Rs.13/- kg.
Cost of coal	- Rs.2 /kg.
GCV of oil	10,000 kCal/kg
GCV of coal	4,200 kCal/kg.

(i) the hourly oil consumption is = $\frac{10,000 \text{ kg} \times (660-60)}{10,000 \text{ kCal} \times 0.82}$ = 731.7 kg/h
it follows 731.7 x 24 x 300/1000 = 5,268 tons per year

(ii) the hourly coal consumption is = $\frac{10,000 \text{ kg} \times (660-60)}{4200 \times 0.72}$ = 1,984 kg/h
it follows 1,984 x 24 x300/1000 = 14,285 tons/year

(iii) (5,268 x13,000 – 14,285 x 2000)/10,000,000 = Rs 3.99 Cr
(iv) Simple pay back period 1.5/(3.99-0.25 x 1.5) = 0.41 years

(vi) The simple payback period in fact cannot be calculated with these few simplistic assumptions because when switching from oil to coal there are additional costs and benefits such as
(a) labour (b) coal processing (c) avoided R & M of oil operation
(d) salvage value of oil boiler

L-2 (i) draw the steam phase diagram in a coordinate system with temperature as (y-axis) and enthalpy as (x-axis)
(ii) explain the major regions of the diagram.

(i)

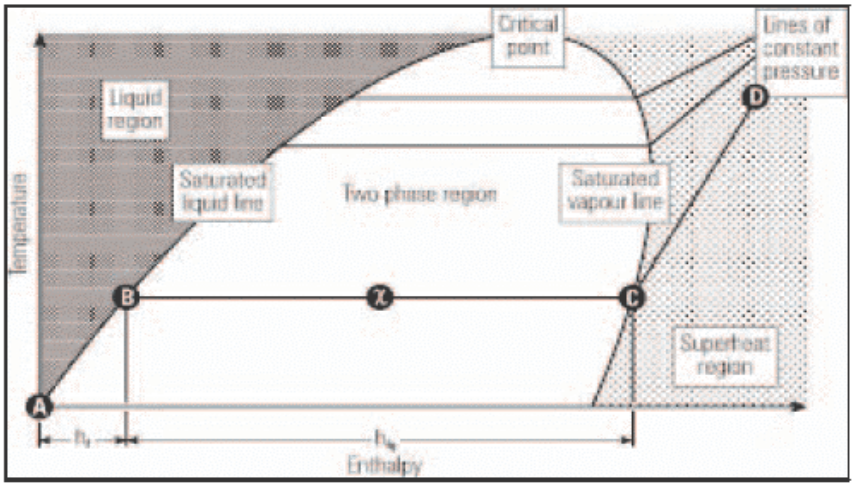


Figure 3.1 Steam Phase Diagram

(ii) Comments

a) to the left of the tilted dome is the liquid region
b) under the dome is the two phase region, which means wet steam
c) to the right of the dome is the superheat steam region
d) the highest point of the dome is the super critical point at 374^{o} C and 221 bar
e) above the critical point is the super critical region where steam has no well defined boiling points.
f) at any point on the dome curve the first x-coordinate B is enthalpy of the saturated liquid, the second x-coordinate C is the enthalpy of the saturated steam and the width C-B is the enthalpy of evaporation from saturated water to saturated steam .

L-3 An energy manager recommends to his superior that in an already well functioning boiler the oil be mixed and should contain 20% water by weight. The manager claims:

(i) this would reduce fuel costs
(ii) boiler efficiency would also improve

Agree or disagree and support your decision by argumentation as well as some calculations. Assume that 1 kg of feed water requires about 600 kCal to evaporate.

(i) One should disagree because 1 kg of furnace oil is replaced by a mixture of 0.8 k of oil and 0.2 kg of water. Even if water costs are

assumed to be zero 1 kg of oil-water mixture cannot cost less than 80% of 1 kg oil.

(ii) One should disagree because this means energy in the oil is required to evaporate additional 0.2 kg of water and heat the water vapor (steam) up to the furnace flue gas temperature. This energy is not any longer available to generate steam. The thermal efficiency is therefore reduced and not improved.

To heat up and evaporate 1 kg of water about 600 kCal of energy are required. In other words 120/8000 = 1.5% of the energy in the oil-water mixture are needed to evaporate this water. This energy is not any longer available to generate steam. Consequently the boiler efficiency is reduced by at least 1.5 %.

L-4 (i) state two examples of heat pump applications
(ii) in which situation are heat pumps most promising?
(iii) draw the schematics of a heat pump system
(iv) briefly discuss each process stage

(i) (a) space heating system, (b) use in plastic factory where chilled water is used to cool injection moulding machines, (c) drying applications such as maintaining dry atmosphere in storage and drying compressed air

(ii) In a situation when both the cooling and heating capabilities of the cycle can be used in combination

(iii)

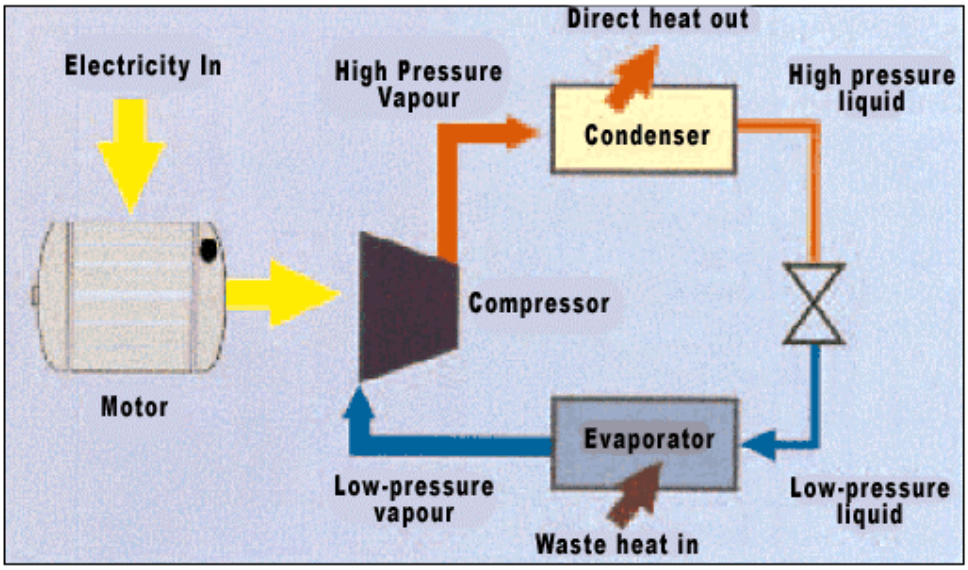


Figure 8.12 Heat Pump Arrangement

(iv) Step 1: in the evaporator the heat is extracted to boil the circulating working fluid
Step 2: the evaporated working fluid is compressed in a compressor rising working fluid temperature and pressure
Step 3: the heat is delivered to the condenser
Step 4: the pressure of the working fluid is reduced in a throttling valve and condensate returned to the compressor

L-5 On the topic of waste heat recovery boilers, explain the following:

(i) Which are typical applications of waste heat boilers?
(ii) How do they differ from ordinary steam boilers?
(iii) In what temperature range do they operate?
(iv) Is it more energy efficient to generate hot water of 80^0 C or saturated steam at 6 bar in a waste heat boiler? Explain

(i) Typical applications are to recover waste heat from medium temperature waste gas streams such as (a) gas turbines, (b) incinerators, (c) furnaces.

(ii) Waste heat boilers are of the water tube type. The hot gases pass over a number of parallel tubes. There is no radiation section but heat transfer is accomplished by convection only. Some have finned water tubes to increase heat transfer

(iii) Gas temperatures are low to medium (400 C to 800 C)

(iv) It is more energy efficient to generate hot water at 80 C than saturated steam at 6 bar because more heat can be extracted from the waste heat stream. In the case of steam generation the waste gas temperature can only be lowered to about 180 C while in the case of hot water the waste heat temperature can be lowered to about 130 or even lower if no excessive Sulfur compounds are present in the flue gas.

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

NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY MANAGERS & ENERGY AUDITORS
Question Papers & Model solutions to the Question Papers

PAPER – 2: Energy Efficiency in Thermal Utilities			
Date: 28.05.2004	**Timings: 1400-1700 HRS**	**Duration: 3 HRS**	**Max. Marks: 150**

General instructions:

- *Please check that this question paper contains **7** printed pages*
- *Please check that this question paper contains **65** 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: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Put a (√) tick mark in the appropriate box in the answer book

1.	The working fluid of a steam thermo-compressor is a) air b) low pressure steam **c) high pressure steam** d) water
2.	A shell and tube heat exchanger is most suitable if **a) a liquid is heating another liquid** b) a gas is heating another gas c) a gas is heating a liquid d) the hot gas is loaded with dust
3.	An economizer raises the boiler feed water by 60^0 C and therefore saves approximately ___ % of fuel. a) 5 **b) 10** c) 15 d) 20
4.	A heat pipe can transfer up to ____ times more thermal energy than copper a) 10 b) 20 c) 50 **d) 100**
5.	Heat wheels are mostly used in a situation of…. a) high temperature exhaust gases **b) heat exchange between large masses of air having small temperature differences** c) heat transfer between a liquid and gas d) corrosive gases

6.	Regenerators utilizing waste heat are widely used in… a) cement industry b) pulp and paper **c) glass melting furnaces** d) aluminium
7.	Air compressor alone consumes about _____ of the energy generated in a gas turbine a) 20-30% b) 30-40% c) 40-50% **d) 50-60%**
8.	Which CHP system has the smallest heat to power ratio with the least flexibility to increase or reduce the ratio? a) back pressure turbine **b) combined cycle** c) extraction condensing steam turbine d) reciprocating engine
9.	The unit for heat-to-power ratio of a CHP plant is **a) kW_{th} / kW_e** b) BTU / kW c) kCal /kW d) kWh_{th} / kW_e
10.	In glass industry waste heat is used for power generation. This type of cogeneration is called a) topping cycle **b) bottom cycle** c) gas turbine cycle d) none of the above.
11.	Pick the wrong statement. The thermal efficiency of a furnace increases by a) preheating combustion air **b) increasing the excess air flow rate** c) reducing the surface heat loss d) minimizing the CO loss and un-burnt losses
12.	The most economic insulation is the thickness where….. a) depreciation costs of insulation and energy cost due to losses are the same **b) the sum of energy cost due to losses and insulation depreciation cost is minimum** c) energy losses are minimized d) energy cost due to losses are minimized.
13.	Which of the four refractories has the highest melting point temperature? **a) Lime (CaO)** b) Silica (SiO_2) c) Titania (TiO_2) d) Alumina (Al_2O_3)
14.	The emissivity of refractory material…. a) increases sharply above 1000^0 C b) will be more or less independent of temperature c) will increase with increasing temperature **d) will decrease with increasing temperature**
15.	High emissivity coatings are applied on a) outer surface of furnace b) refrigeration piping **c) inner surface of furnace** d) none of the above
16.	The heat loss rate from a surface is expressed in **a) Watt** b) Watt/$m^2 - {}^0K$ c) Watt/$m^2 - {}^0C$ d) Joules

17.	Which statement is incorrect a) higher density refractory has a lower thermal conductivity b) a higher emissivity means higher radiation of heat **c) a higher emissivity means lower absorption of heat** d) a black colored body radiates more than a glossy white colored one.
18.	Fluidized bed combustion takes place in a temperature range of a) 600^0C - 700^0C **b) 850^0C - 950^0C** c) above 1000^0C d) about 500^0C
19.	The low combustion temperatures in fluidized bed combustion boilers results in minimal formation of **a) NO_x** b) NO_x and SO_x c) CO_2 d) CO
20.	SO_x emissions in a FBC boiler fired with high sulfur coal are controlled by adding ____ to the bed a) Magnesia **b) Limestone** c) Sand d) Silica
21.	In circulating fluidized bed combustion boilers most of the heat transfer takes place… a) inside the combustion zone b) bed tubes **c) outside of the combustion zone** d) super heater tubes
22.	De-aeration of boiler feed water is referred to as **a) removal of dissolved gases** b) removal of silica from feed water c) removal of TDS from feed water d) phosphate treatment of feed water
23.	Pre-heating of combustion air in an oil fired furnace by 20^0 C will save about ___% of fuel a) 0.3 **b) 1** c) 1.5 d) 0.6
24.	To drain condensate from main steam line, the following type of trap is a suitable trap. a) float b) bimetallic **c) thermodynamic** d) none of the above
25.	Increase in stack gas temperature of 22^0 C due to tube fouling or other causes will increase oil consumption in an oil fired boiler by about. **a) 1%** b) 2% c) 3.5% d) 4%
26.	Water hammer in a steam system is caused by **a) collected condensate hits obstructions** b) leaking pipe joints c) slow moving steam d) continuous slope in direction of flow
27.	Which data is not required to calculate boiler efficiency by the indirect method **a) steam flow rate** b) stack gas temperature c) ambient temperature d) energy content of fuel

28.	Latent heat at the critical point of a steam phase diagram is a) infinite b) 540 kCal/kg **c) zero** d) none of the above
29.	Increase of steam pressure has which of the following effect on steam **a) steam temperature goes up and enthalpy of evaporation goes down** b) steam temperature and enthalpy of evaporation go down c) steam temperature goes up and enthalpy of evaporation goes up d) specific volume goes down and enthalpy of evaporation goes up
30.	Scale losses in reheating furnaces will increase with a) decrease in excess air b) decrease in furnace temperature **c) increase with excess air** d) are not correlated to temperature
31.	An air film inside in a steam pipe may be _____ times more resistant to heat transfer then the steel the steam pipe is made of. a) 200 – 1000 **b) 1500 – 3000** c) 4000 – 8000 d) 8000 – 16000
32.	The best steam for indirect heating in most industrial process is **a) as dry as possible** b) super heated steam c) wet steam d) as wet as possible
33.	Pressure drop through a steam pipe is inversely proportional to a) diameter b) square of diameter **c) fifth power of diameter** d) cube of diameter
34.	In an oil fired burner, the excess air level _____ towards the highest turndown ratio for efficient combustion. a) decreases **b) increases** c) not affected d) none of the above
35.	What is the most effective way to avoid ambient air infiltration into a continuous furnace a) close all openings b) increase the chimney height c) operate at about 90% capacity **d) reduce negative pressure inside the furnace**
36.	Black body radiation is a) linear proportional to temperature b) proportional to the fourth power of the temperature of the body **c) proportional to the fourth power of the absolute temperature of the body** d) proportional to the square of the body surface area
37.	Steam at 6 bar has a sensible heat of 159.33 kCal/ kg and latent heat of 498.59 kCal/ kg. If the steam is 95% dry than the total enthalpy is a) 625 kCal/ kg b) 649.95 kCal/ kg c) 553 kCal/ kg **d) 633 kCal/ kg**
38.	In which type of furnace operation is a low mass ceramic fiber insulation most suitable to reduce specific fuel consumption **a) batch type furnace** b) continuous Hoffmann tunnel kiln

	c) rotary high temperature furnace d) low temperature furnace
39.	Which loss is the highest in a typical re-heating furnace operating at 1300^0 C? **a) flue gas loss** b) wall loss c) necessary opening loss d)cooling water loss
40.	In a batch type furnace the following energy efficiency measure would be the most controversial a) increasing the insulation at the hot temperature side **b) increasing the insulation at the outer surface of the furnace** c) pre-heating the combustion air d) reducing excess air.
41.	Specific heat in kCal/kg -^{0}C of fuel oil is in the range of a) 0.15 – 0.20 **b) 0.22 – 0.28** c) 0.29 – 0.32 d) none of the above
42.	Grade B Indian coal has a energy content range (in kcal/kg) of a) 3360-4200 b) 4200-4900 c) 4940-5600 **d) 5600-6200**
43.	Which is the common coal firing system used in Indian thermal power plants? **a) pulverized coal firing** b) stoker firing c) fluidized bed d) pressurized bed
44.	Which of the following fuel requires maximum air for stochiometric combustion? a) Butane b) Propane **c) Hydrogen** d) Coal
45.	Stochiometric air required for combustion of Bagasse is about a) 13.7 **b) 3.2** c) 6 d) 18
46.	Which fuel releases the most energy per kg on complete combustion a) Carbon b) Sulphur c) Nitrogen **d) Hydrogen**
47.	How many kg of CO_2 are produced in complete combustion of 16 kg of Methane? a) 42 **b) 44** c) 16 d) none of the above
48.	Theoretical CO_2 of a fuel in % is 15.5. The measured CO_2 in the stack gas is 11% by volume. The percentage of excess air will be **a) 40.9%** b) 38.7 % c) 240.9 % d) 140.9 %
49.	Evaporation ratio (steam to fuel ratio) of an oil fired efficient boiler is in the range of a) 5 - 6 **b) 13 – 14** c) 1 - 3 d) 7 – 9
50.	A rise in conductivity of boiler feed water indicates a) drop in the total dissolved solids in boiler water b) more steam generation c) greater purity of feed water **d) rise in the total dissolved solids in boiler water**

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

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 10 x 5 = 50**

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

S-1 (i) State the stochiometric combustion equation for Hydrogen and Carbon.
(ii) How many kg of water are generated by complete combustion of 1 kg of Hydrogen?
(iii) How many kg of Carbon Dioxide are generated by complete combustion of 1 kg of Carbon?

(i) $2H_2 + O_2 = 2H_2O$ **or** $H_2 + ½ O_2 = H_20$
4 + 32 = 36 (only for reference and further calculation)

$C + O_2 = CO_2$
12 + 32 = 44 (only for reference and further calculation)

(ii) 36/4 = 9 kg of water are generated for each kg of Hydrogen (
(iii) 44/12 = 3.67 kg of Carbon Dioxide are generated for each kg of Carbon.

S-2 Assume the stochiometric (theoretical) air to fuel ratio of furnace oil is 13.8. The burner operates at 15% excess air. Calculate the mass of stack gas generated from combustion of one kg of oil.

(i) Mass of air + mass of fuel = mass of stack gas
1.15 x 13.8 + 1 = 16.87 kg

S-3 (i) Explain the difference between the indirect and direct method of boiler efficiency evaluation
(ii) State both equations.

(i) The difference is that in the direct method two major flows (steam and fuel flow) must be measured to calculate the energy streams for steam as useful output and energy input from the fuel. The direct method does not identify or measure energy losses. In the indirect method no flow measurements are necessary and this method identifies and measures major losses and estimates not so major losses.

$$\eta \text{ (direct)} = \frac{\text{Heat output x 100}}{\text{Heat input}} \text{ in \%}$$

A more precise formulation is to replace heat output by "useful heat output" or "absorbed heat".

In the indirect method the losses are either measured or estimated and subtracted from 100.

η (indirect) = 100 – sum of losses in %.

S-4 Explain why group trapping is not recommended with steam traps.

a) group trapping normally causes water logging
b) group trapping causes loss of output
c) pressure in the various steam spaces will be different, i.e. pressure at the drain outlet of a heavily loaded unit will be less than in the case of one that is lightly loaded. Since the traps discharge condensate due to differential pressure, the condensate from the heavily loaded one finds it difficult to reach the trap.

S-5 A reheating furnace output is 5 tons/hour. Thermal efficiency is claimed to be 20%. Specific heat of billet is 0.12 kcal/kg^{o} C. Billets enter the furnace at 50^{o}C and leave at 1200^{o}C. Calculate the hourly oil consumption in liter if GCV of oil is 9,000 kCal/liter.

Efficiency = $\frac{\text{heat absorbed in the stock}}{\text{heat in the fuel}}$ = 0.20 = $\frac{\text{5000 x 0.12 (1200-50)}}{\text{liter x 9,000}}$

it follows, oil consumption is 383.3 liter/hour

S-6 How does high emissivity coating in a furnace chamber helps in reducing energy consumption?

(i) promotes rapid and efficient transfer of heat
(ii) more uniform heating
(iii) extended life of refractory
(iv) for intermitted furnaces or where rapid heating is required such coating has reduced energy consumption by 8% to 20%.

S-7 (i) Which sources of heat can be recovered from a 2 MW reciprocating engine cogeneration system? and
(ii) What is roughly the temperature level of these waste streams?

(i) There are essentially two work streams such as a) exhaust gas b) coolers for water, air and oil
(ii) The temperature level of the exhaust gas streams are about 350^{0} C - 450^{0} C from exhaust gas and above 100^{0} C from cooling water.

S-8 (i) list prime movers for cogeneration, and
(ii) state the one with the highest efficiency.

(i) list of prime movers

a) steam turbine – back pressure
b) steam turbine – extracting and condensing
c) gas turbine
d) reciprocating engine

(ii) the back pressure steam turbine cogeneration system is the most efficient if 100% of the back pressure exhaust steam is used.

S-9 Calculate the blow down rate in kg/hr from a boiler with an evaporation rate of 5 tons/hr, if the maximum permissible TDS in the boiler water is 4000 ppm and with 15% make up water addition. The feed water TDS is 300 ppm

Blowdown (%) = (feedwater TDS in %) x (% Makeup)
Permissible TDS in Boiler – Feedwater TDS

= 300 x 15/(4000-300) = 1.22% or 5000 x 1.22/100 = 60.8 kg/hr

(OR)

Blowdown (%) = feedwater TDS x % Makeup
Maximum Permissible TDS in Boiler water

Blowdown (%) = 300 x 15 / 4000 = 1.13% or 5000 x 1.13/100 = 56.5 kg/hr

(Marks are to be awarded if the candidates have worked out the solution based on any one of the above formula.)

S-10 A firm wants to recover waste heat in a flue gas stream of 1800 kg/hour from a furnace. Specific heat of flue gas is 0.23 kCal/kg^0 C.

(i) calculate the heat recovered if the heat exchanger has an efficiency of 97% and temperature of flue gas drops from 900^0 C to 220^0 C across the heat exchanger.

(ii) How many liters of water per hour can be heated by 40^0 C from this waste stream?

(i) Heat transferred to water = 1,800 x 0.97 x 0.23 x (900 – 220)
= 273,074.4 kCal/hour

(ii) Solve for 273,074.4 = litres x 1 x 40

It follows 6827 litres per hour.

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

Section - III: LONG DESCRIPTIVE QUESTIONS Marks: 5 x 10 = 50

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

L-1 It is proposed to replace an oil-fired boiler of 10 tons per hour with a coal fired boiler of equivalent capacity. With the help of the data provided find out the following:

(i) the annual oil consumption in tons per year?
(ii) the annual coal consumption in tons per year?
(iii) estimate annual fuel cost savings in Crore rupees
(iv) simple pay back period of the project, assuming the coal fired boiler costs Rs.1.5 Crore and annual repair and maintenance costs of the coal fired boiler are 25% of capital cost.
(v) Comment about accuracy of the calculated payback period.

Operation data

Heat content of steam	760 kCal/kg.
Feed water inlet temperature	70^0 C
Daily operating hours	24
Number of days / year	280
Efficiency of oil fired boiler	80%
Efficiency of coal fired	74%
Cost of oil	Rs.14/- kg.
Cost of coal	Rs.1.4 kg.
GCV of oil	10,000 kCal/kg
GCV of coal	4,400 kCal/kg.

(i) the hourly oil consumption is $\frac{10{,}000 \text{ kg} \times (760-70)}{10{,}000 \text{ kCal} \times 0.80} = 862.5$ kg/h

it follows 862.5 x 24 x 280/1000 = 5796 tons per year

(ii) the hourly coal consumption is $\frac{10{,}000 \text{ kg} \times (760-70)}{4{,}400 \times 0.74} = 2{,}119$ kg/h

it follows 2,119 x 24 x280/1000 = 14240 tons/year

(iii) Savings (5796 x14,000 – 14240 x 1,400)/10,000,000 = Rs 6.12 Cr

(iv) Simple pay back period 1.5/(6.12-0.25 x 1.5) = 0.26 years

(v) The dynamic payback period in fact cannot be calculated with these few simplistic assumptions because when switching from oil to coal there are additional labor and coal processing cost, which do not exist for oil. In addition the avoided repair and maintenance costs of the oil operation should be added. Note, that arguing the simple payback period method is inaccurate because of the time value of money is a wrong statement in this context where payback is in any case shorter than 1 year.

L-2 (i) Explain why dry saturated steam is preferred over wet or super heated steam for industrial process heating

(ii) Complete the enthalpy equation h_g = ? for wet steam and name the variables.
(iii) Why should one use dry steam at the lowest possible pressure for indirect steam heating.

(i) (a) Superheated steam gives up heat at a slower rate then saturated steam.
(b) wet steam has a lower heat content than dry steam.
(c) dry steam condenses quickly and provides a faster heat transfer (3 marks)

(ii) $h_g = h_f + X.h_{fg}$
h_f = enthalpy of saturated water at a given pressure
h_{fg} = enthalpy of evaporation of saturated water to saturated steam
h_g = enthalpy of saturated steam
X= dryness fraction of wet steam

(iii) The latent heat of steam increase with reduction of steam pressure and only latent heat takes part in the indirect heating process.

L-3 Explain incomplete combustion with reference to

(i) causes of incomplete combustion
(ii) the products of incomplete combustion

(i) In general the three T apply: Temperature in the combustion chamber should be high enough to ignite and maintain combustion, Turbulence helps for good mixing of fuel and oxygen and enough Time should be given to the fuel in the combustion chamber

The causes of incomplete combustion may be either of a chemical/kinetic or a physical nature.

Major causes of physical nature are insufficient atomization of oils, wrong sizing of coal, wrong pressure of oil, combustion flame coming too close to a "colder" surface and therefore freezing the chemical reaction, worn out burner nozzles, insufficient preheating of oil. In general bad mixing of fuel and combustion air and not enough turbulence.

The major chemical cause for incomplete combustion is insufficient amount of combustion air and therefore implicitly not enough oxygen to burn Carbon and Hydrogen to CO_2 and $H2_O$. The amount of combustion air must be more then the stochiometric or theoretical air for Carbon and Hydrogen.

(ii) The products of incomplete combustion are Carbon Monoxide (CO), as well as fine Carbon or soot, and liquid Higher Hydrocarbons.

L-4 (i) State the general equation for heat loss from a hot wall or pipe surface.
(ii) Name each variable and state SI - units of these variables

(ii) Where does the thermal conductivity of the wall or pipe structure enter in this equation?

(i) $H = h \times A \times (T_h - T_a)$

(ii) variables and units

H = heat loss in Watt (=Joules/s and therefore a heat loss rate)
h = heat (or film heat) transfer coefficient in $W/m^2\ ^oK$ (same as $W / m^2\ ^oC$)
A = outer surface in m^2
T_h = hot surface temperature in degree Centigrade
T_a = ambient (surroundings) temperature in degree Centigrade

(iii) Thermal conductivity of the wall does enter this equation through T_h the hot surface temperature but not through h.

(OR)

S = [10 + (Ts-Ta)/20] x (Ts-Ta)

Where

S	=	Surface heat loss in kCal/hr m^2
Ts	=	Hot surface temperature in K
Ta	=	Ambient temperature in K

(OR)

$$Q = a\,x\,(t_1 - t_2)^{5/4} + 4.88\,E\,x\left(\left(\frac{t_1 + 273}{100}\right)^4 - \left(\frac{t_2 + 273}{100}\right)^4\right)$$

where Q: Quantity of heat released (kCal/hr)
a : factor regarding direction of the surface of natural convection ceiling = 2.8, side walls = 2.2, hearth = 1.5
t_l : temperature of external wall surface of the furnace (°C)
t_2 : temperature of air around the furnace (°C)
E: emissivity of external wall surface of the furnace

L-5 (i) Draw the schematic for a 2 MW internal combustion engine used as cogeneration system to generate power and hot water by cold water.

(ii) How many cubic meters of water can be heated from 30^0 C to 60^0 C per hour if the power generation unit has an efficiency of 40% for the generation of electricity without the waste heat recovery components and 82% with the waste heat recovery component. Assume a fuel oil consumption of 220 gram/kWh electricity at an output of 1.8 MW and GCV of oil 10,000 kCal/kg

(i)

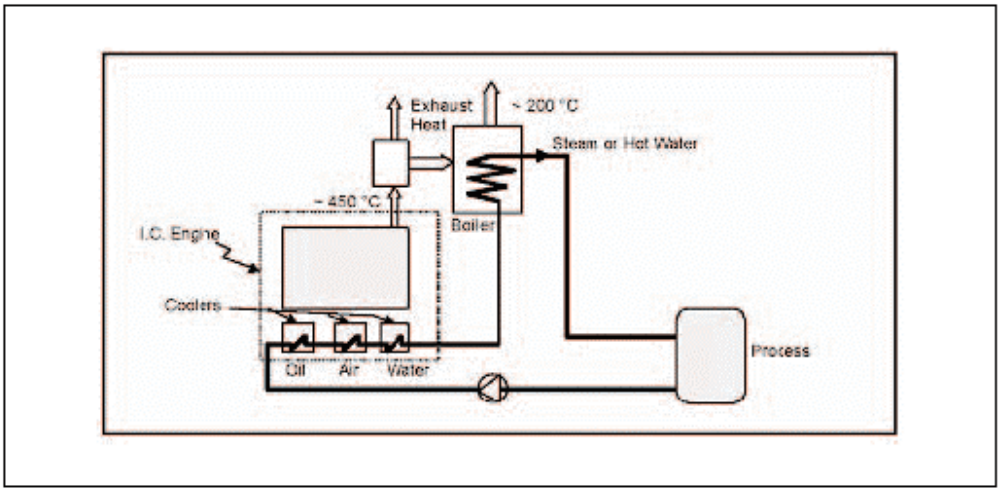


Figure 7.5 Schematic Diagram of Reciprocating Engine Cogeneration

(ii) Total fuel energy available is 0.22 x 10,000 x 1,800 = 3,960,000 kCal/h

Fuel energy per hour converted to electricity is 0.4 x 0.22 x 10,000 x 1800 = 1,584,000 kCal/h.

Fuel energy loss neither converted to electricity nor warm water 0.18 x 0.22 x10,000 x1,800 = 712,800 kCal/h

Fuel energy available to heat water 3,960,000–1,584,000–712,800= 1,663,200 kCal/h
Consequently 1,663,200 / [(60-30)x1000] = 55 cubic meters of water per hour

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

NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY MANAGERS & ENERGY AUDITORS

Question Papers & Model solutions to the Question Papers

PAPER – 3:	**Energy Efficiency in Electrical Utilities**
Date: 29.05.2005	Timings: 0930-1230 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **65** 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: OBJECTIVE TYPE

Marks: 50 x 1 = 50

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Put a (√) tick mark in the appropriate box in the answer book

1.	The voltage drops in transmission / distribution line depends on ____. a) reactance and resistance of the line b) current in the line c) length of the line **d) all of the above**
2.	Power factor is the ratio of **a) kW/kVA** b) kVA/kW c) kVAr/kW d) kVAr/kVA
3.	If the reactive power drawn by a particular load is zero, it means the load is operating at a) lagging power factor b) leading power factor **c) unity power factor** d) none of the above
4.	Select the ideal location of installing capacitor banks, which will reduce the distribution loss to the maximum extent. a) main sub-station bus bars **b) motor terminals** c) motor control centre d) distribution transformers

5.	A 10 HP/7.5 kW, 415 V, 14.5 A, 1460 RPM, 3 phase rated induction motor, after decoupling from the driven equipment, was found to be drawing 3 A at no load. The current drawn by the motor at no load is high because of a) faulty ammeter reading b) very high supply frequency at the time of no load test c) lose motor terminal connections **d) very poor power factor as the load is almost reactive**
6.	If voltage applied to a 415 V rated capacitors drops by 5 %, its VAr output drops by about____. a) 5% **b) 10%** c) 19% d) none of the above
7.	Which of the following is not a positive displacement compressor a) Roots blower b) Screw Compressor **c) Centrifugal Compressor** d) Reciprocating Compressor
8.	Which of the factors will indicate the performance of a rewound induction motor? a) no load current b) stator winding resistance c) air gap **d) all the above**
9.	A six pole induction motor operating at 50 Hz, with 1% slip will run at an actual speed of a) 1000 RPM b) 1010 RPM **c) 990 RPM** d) none of the above
10.	With decrease in design speed of squirrel cage induction motors the required capacitive kVAr for reactive power compensation for the same capacity range will **a) increase** b) decrease c) not change d) none of the above
11.	The ratio of current drawn by the induction motor to its rated current does not reflect true loading of the motor at partial loads mainly due to a) increased motor slip **b) decreased operating power factor** c) decreased motor efficiency d) none of the above
12.	For every 4°C rise in the air inlet temperature of an air compressor, the power consumption will normally increase by___ percentage points for the same output. **a) 1** b) 2 c) 3 d) 4
13.	Typical acceptable pressure drop in mains header at the farthest point of an industrial compressed air network is **a) 0.3 bar** b) 0.5 bar c) 0.7bar d) 1.0 bar
14.	Vertical type reciprocating compressor are used in the cfm capacity range of **a) 50-150** b) 200-500 c) 500-1000 d) 1000 and above
15.	A battery of two reciprocating 250 cfm belt driven compressors installed in a centralized station, were found to be operating at the same loading period of 60% and unloading period of 40%. The least cost solution to reduce wastage of energy in this case would be a) switching off one compressor **b) reducing appropriately the motors pulley sizes** c) reducing appropriately the compressors pulley sizes d) none of the above

16.	With increase in condensing temperature in a vapor compression refrigeration system, the specific power consumption of the compressor for a constant evaporator temperature will **a) increases** b) decreases c) sometime increases and sometime decreases d) remains the same
17.	With increase in evaporator temperature in a vapor compression refrigeration system, while maintaining a constant condenser temperature, the specific power consumption of the compressor will a) increase **b) decrease** c) sometime increase and sometime decrease d) remains the same
18.	The refrigeration load in TR when 15 m^3/hr of water is cooled from 21^o C to 15 ^{o} C is about a) 7.5 b) 32 **c) 29.8** d) none of the above
19.	Coefficient of Performance (COP) for a refrigeration compressor is given by **a) Cooling effect (kW) / Power input to compressor (kW)** b) Power input to compressor (kW) / cooling effect (kW) c) Q x C_P x (Ti – To) / 3024 d) none of the above
20.	The efficiency of backward-inclined fans compared to forward curved fans is__ **a) higher** b) lower c) same d) none of the above
21.	_____ fans are known as “non-overloading“ because change in static pressure do not overload the motor a) radial b) forward- curved **c) backward-inclined** d) tube- axial
22.	A 100 cfm reciprocating compressor was observed to be operating at load - unload pressure setting of 6.0 kg/cm^2g and 7.5 kg/cm^2g respectively. This situation will result in a) increased leakage loss in air distribution system b) increased loading timings of the compressor c) increased energy consumption of the compressor **d) all the above**
23.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by a) suction pressure/discharge pressure **b) discharge pressure/suction pressure** c) suction pressure/ (suction pressure + discharge pressure) d) discharge pressure/ (suction pressure + discharge pressure)
24.	In centrifugal fans, airflow changes direction a) once **b) twice** c) thrice d) none of the above
25.	Reducing the fan RPM by 10% decreases the fan power requirement by a) 10% **b) 27%** c) 33% d) none of the above
26.	It is possible to run pumps in parallel provided their_____ are similar a) suction head b) discharge heads **c) closed valve heads** d) none of the above

27.	The operating point in a pumping system is identified by a) point of intersection of system curve and efficiency curve b) point of intersection of pump curve and theoretical power curve **c) point of intersection of pump curve and system curve** d) none of the above
28.	Input power to the motor driving a pump is 30 kW. The motor efficiency is 0.9 and pump efficiency is 0.6. The power transmitted to the water is **a) 16.2 kW** b) 18.0 kW c) 27.0 kW d) none of the above
29.	The static pressure of a fan running at 500 RPM is 200 mm wc. If it has to be increased to 250 mmwc then the new speed of the fan would be **a) 625 RPM b) 400 RPM c) 1250 RPM d) 750 RPM** (One mark to be awrded to all)
30.	If inlet and outlet water temperatures of a cooling tower are 42°C and 34°C respectively and atmospheric DBT and WBT are 39 °C and 30 °C respectively, then the approach of cooling tower is a) 3°C **b) 4°C** c) 5°C d) 8°C
31.	Which one from the following types of cooling towers consumes less power? a) Cross-flow splash fill cooling tower b) Counter flow splash fill cooling tower **c) Counter flow film fill cooling tower** d) None of the above
32.	Which one of the following is true to estimate the range of cooling tower? a) Range = Cooling water inlet temperature – Wet bulb temperature b) Range = Cooling water outlet temperature – Wet bulb temperature **c) Range =** $\frac{\text{Heat load in kCal/ h}}{\text{Water circulation in liters/ h}}$ d) None of the above
33.	Which of the following ambient conditions will evaporate minimum amount of water in a cooling tower a) 35 °C DBT and 25 °C WBT b) 40°C DBT and 36°C WBT c) 35 °C DBT and 28 °C WBT **d) 38 °C DBT and 37 °C WBT**
34.	Small by-pass lines are installed in pumps some times to _____. a) save energy b) control pump delivery head **c) prevent pump running at zero flow** d) reduce pump power consumption
35.	Cycles of concentration in circulating water (C.O.C) is the ratio of **a) dissolved solids in circulating water to the dissolved solids in make up water** b) dissolved solids in make up water to the dissolved solids in circulating water c) dissolved solids in evaporated water to the dissolved solids in make up water d) none of the above
36.	One lux is equal to ___. a) one lumen per ft^2 **b) one lumen per m^2** c) one lumen per m^3 d) none of the above

37.	Color rendering index of Halogen lamps compared to low pressure sodium vapor lamps is a) poor **b) excellent** c) average d) very poor
38.	Which of the following options reduces the electricity consumption in lighting system in a wide spread plant? a) replacing 150 W HPSV lamps with 250 W HPMV lamps b) maintaining 260 V for the lighting circuit with 220 V rated lamps **c) installing separate lighting transformer and maintaining optimum voltage** d) none of the above
39.	If voltage is reduced from 230 V to 190 V for a fluorescent tube light, it will result in a) increased power consumption **b) reduced power consumption** c) increased light levels d) no change in power consumption
40.	What is the typical frequency of a high frequency electronic ballast? a) 50 Hz b) 50kHz **c) 30 kHz** d) 60 Hz
41.	Which combination of readings as indicated by the panel mounted instruments of a DG Set would give the indications of proper capacity utilisation of diesel engine and generator a) kW & Voltage b) kVA & kVAr **c) kW & KVA** d) none of the above
42.	Lower power factor of a DG set demands_____ a) lower excitation currents **b) higher excitation currents** c) no change in excitation currents d) none of the above
43.	The main precaution to be taken care by the waste heat recovery device manufacturer to prevent the problem in a DG set during operation is: a) temperature rise **b) back pressure** c) over loading of waste heat recovery tubes d) turbulence of exhaust gases
44.	In a DG set, the generator is generating 1000 kVA, at 0.7 PF. If the specific fuel consumption of this DG set is 0.25 lts/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour. a) 230 litre b) 250 litre **c) 175 litre** d) none of the above
45.	Which of the following losses is the least in DG sets: a) cooling water loss b) exhaust loss c) frictional loss **d) alternator loss**
46.	Slip power recovery system is used in a) DC motor b) synchronous motor c) squirrel cage induction motor **d) slipring induction motor**
47.	The basic functions of an electronic ballast fitted to a fluorescent tube light exclude one of the following a) to stabilize the gas discharge b) to ignite the tube light c) to supply power to the lamp at very high frequency **d) to supply power to the lamp at supply frequency**

48.	Select the feature which does not apply to energy efficient motors by design: a) energy efficient motors last longer b) starting torque for efficient motors may be lower than for standard motors **c) energy efficient motors have high slips which results in speeds about 1% lower than standard motors** d) energy efficient motors have low slips which results in speeds about 1% higher than standard motors
49.	Energy savings potential of variable torque applications compared to constant torque application is: **a) higher** b) lower c) equal d) none of the above
50.	Maximum demand controllers are used to a) control the power factor of the plant b) switch off essential loads in a logical sequence **c) switch off non-essential loads in a logical sequence** d) none of the above

……. End of Section – I …….

Section – II: SHORT DESCRIPTIVE QUESTIONS

Marks: 10 x 5 = 50

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

S-1. Compute the maximum demand recorded for a plant where the recorded load is as mentioned below in the recording cycle of 30 minutes.

- 100 kVA for 10 minutes
- 200 kVA for 5 minutes
- 50 kVA for 10 minutes
-150 kVA for 5 minutes

The MD recorder will be computing MD as:

$$\frac{(100 \times 10) + (200 \times 5) + (50 \times 10) + (150 \times 5)}{30} = 108.3 \text{ kVA}$$

S-2. Why is it beneficial to operate motors in star mode for induction motors loaded less than 50% ?

Operating in the star mode leads to a voltage reduction by a factor of '$\sqrt{3}$'. Motor output falls to one-third of the value in the delta mode, but performance characteristics as a function of load remain unchanged. The motor gets derated and behaves as a smaller motor. Consequently the % loading of the motor increases. Thus, full-load operation in star mode gives higher efficiency and power factor than partial load operation in the delta mode. However, motor operation in the star mode is possible only for applications where the torque-to-speed requirement is lower at reduced load

S-3 In an engineering industry, while conducting a leakage test in the compressed air system, following data for a reciprocating air compressor was recorded:

Compressor capacity = 35 m^3 per minute
Average load time = 90 seconds
Average unload time = 360 seconds
Find out the leakage quantity in m^3 per day (assume 20 hours per day of operation)

% Leakage in the system

Load time (T) : 90 seconds

Un load time (t) : 360 seconds

% leakage in the system : $\frac{T}{(T+t)} x100$

: $90/(90+360)\,x100$

: **20 %**

Leakage quantity : **0.2 x 35**

: **7 m^3/min X 60 X 20**

: **8400 m^3/ day**

S-4 What is the main difference between vapor compression refrigeration (VCR) and Vapour Absorption Refrigeration (VAR) system ?

- VCR uses electric power for the compressor as main input while VAR uses a source of heat

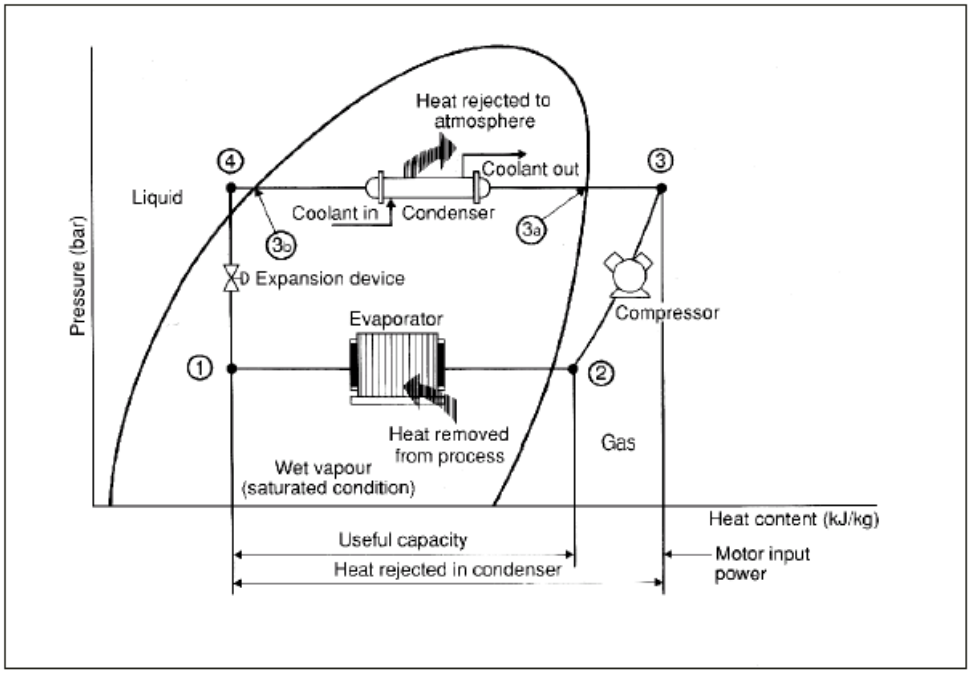
- VCR uses compounds of hydrogen, fluorine and carbon as refreigerants while VAR uses water
- VCR works under pressure while VAR works under vacuum
- VCR has a high COP while VAR has a low COP
- *Any other relevant point……*

S-5 How the heat is absorbed, or removed from a low temperature source and transferred to a high temperature source in a vapour compression system ?

Vapour Compression Refrigeration

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source.

(OR)



1 - 2 Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 - 3 The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy input into the compression process is transferred to the refrigerant.

3 - 4 The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) desuperheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 - 1 The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator

S-6 Find out the blow down rate from the following data. Cooling Water Flow Rate is 500 m^3/hr. The operating range is 8°C. The TDS concentration in circulating water is 1800 ppm and TDS in make up water is 300 ppm.

Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x ($T_1 - T_2$)

= 0.00085 x 1.8 x 500 x 8

= 6.12 m^3/hr

COC = (TDS in circulating water / TDS in make up water)

= 1800 / 300

= 6

Blowdown = Evaporation loss / (COC – 1)

= 6.12 / (6 – 1)

= 1.224 m^3/hr

S-7 What is the role of an electronic ballast in a fluorescent tube light ?

In an electric circuit the ballast acts as a stabilizer. Fluorescent lamp is an electric discharge lamp. The two electrodes are separated inside a tube with no apparent connection between them. When sufficient voltage is impressed on these electrodes, electrons are driven from one electrode and attracted to the other. The current flow takes place through an atmosphere of low-pressure mercury vapour.

Since the fluorescent lamps cannot produce light by direct connection to the power source, they need an ancillary circuit and device to get started and remain illuminated. The auxillary circuit housed in a casing is known as ballast.

S-8. Explain how stator and rotor I^2R losses are reduced in an energy efficient motor.

Stator I^2R: Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers resistance (R) of the windings and reduces losses due to current flow (I).

Rotor I^2R :Use of larger rotor conductor bars increases size of cross section, lowering conductor resistance (R) and losses due to current flow (I)

S-9. A centrifugal pump is pumping 70 m^3/hr of water with a discharge head of 5 kg/cm^2 g and a negative suction head of 3 metres. If the power drawn by the motor is 16 kW, find out the pump efficiency. Assume motor efficiency as 90% and water density as 1000 kg/m^3.

Hydraulic power P_h = Q (m^3/s) x Total head, $h_d - h_s$ (m) x ρ (kg/m^3) x g (m/s^2) / 1000

Q = 70/3600 m^3/s , $h_d - h_s$ = 50 – (-3) = 53 m

Hydraulic power P_h = (70/3600) x 53 x 1000 x 9.81 / 1000

= 10.1 kW

Pump shaft power = 16 kW x 0.9

= 14.4 kW

Pump efficiency = hydraulic power / pump shaft power

= 10.1 /14.4

= 70 %

S-10. A genset is operating at 800 kW loading with 480^{o}C exhaust gas temperature. The DG set generates 8 kg gas/ kWh generated, and specific heat of gas at 0.25 kCal/ kg ^{o}C. A heat recovery boiler is installed after which the exhaust gas temperature reduces to 180 ^{o}C. How much steam will be generated at 3 kg/ cm^{2} with enthalpy of 650.57 kCal/ kg. Assume boiler feed water temperature as 80^{o}C.

Quantity of flue gas = 800 x 8

= 6400 kg/hr

Heat recovered = 6400 x 0.25 x (480 – 180)

= 4,80,000 kcal/hr

Quantity of steam generated = 4,80,000 / (650.57 – 80)

(Reduce one mark if efficiency is assumed)

= 841 kg/hr

……. End of Section - II …….

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 5 x 10 = 50

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

L-1. (a) A 3 phase, 415 V, 110 kW induction motor is drawing 50 kW at a 0.75 PF.

Calculate the capacitor rating requirements at motor terminals for improving PF to 0.95. Also, calculate the reduction in current drawn and kVA reduction, from the point of installation back to the generating side due to the improved PF.

(b) A process plant consumes of 125,000 kWh per month at 0.9 Power Factor (PF). What is the percentage reduction in distribution losses per month if PF is improved up to 0.96 at load end?

a) kVAr Rating = kW [Tan ϕ1 – tan ϕ2]

Cos ϕ1 = 0.75, ϕ1 = Cos (inv) 0.75 = 41.41, Tan ϕ1 = 0.882
Cos ϕ2 = 0.95, ϕ2 = Cos (inv) 0.95 = 18.2 , Tan ϕ2 = 0.329

kVAr Rating = 50 kW (0.882 – 0.329)

= 27.65 kVAr

Current drawn at 0.75 PF = 50 / $\sqrt{3}$ x 0.415 x 0.75

= 92.8 A

Current drawn at 0.95 PF = 50 / $\sqrt{3}$ x 0.415 x 0.95

= 73.3 A

Reduction in current drawn = 92.8 – 73.3

= 19.5 A

Initial kVA at 0.75 PF = 50 / 0.75

= 66.7 kVA

kVA at 0.95 PF = 50 / 0.95

= 52.6 kVA

Reduction in kVA = 66.7 – 52.6

= 14.1 kVA

(OR)

Reduction in kVA $= (\sqrt{3}\ VI)_{old} - (\sqrt{3}\ VI)_{new}$
$= (\sqrt{3} \times 0.415 \times 92.8) - (\sqrt{3} \times 0.415 \times 73.3)$
$= 66.68 - 52.65$
$= 14.03$ kVA

b) % Reduction in distribution losses $= \left[1 - (PF_1 / PF_2)^2\right]$

$= [1 - (0.9/0.96)^2]$

$= 0.121$

$= 12.1\ \%$

L-2. a) A V-belt driven reciprocating instrument air compressor was found to be maintaining a distribution system pressure of 7 kg/cm^{2}g. 20% of the instrument air was used for control valves installed in a boiler house and requiring 6.5 kg/cm^{2}g, whereas balance 80% of the instrument air was used for other application requiring 4 kg/cm^{2}g. What would you like to advise in this situation?

1. **Have a separate small compressor operating at 6.5 to 7 kg/cm^{2}g to meet the boiler house control valve requirement located near the boiler house.**

2. **The existing compressor can operate with the pressure setting changed to 4 to 5 kg/cm^{2}g**

3. **Since 20 % of the load on the existing compressor is transferred to new compressor and with the reduced pressure setting leakage loss will be less. Now this compressor will be unloading for a longer time. Hence reduce motor pulley sizes to reduce the RPM thus reducing the output and the unloading time.**

b) An energy auditor observes the following load unload condition on two similar reciprocating air compressor installed in two separate industrial locations (A & B)

	A	B
Load setting (kg/cm2g)	6.5	6.5
Unload setting (kg/cm2g)	6.8	7.5

The energy auditor concludes that at location B, the compressed air system in operation is inefficient. Do you agree with his observation. Justify your reply with atleast two reasons in support of your argument

Energy auditor is right as
a) system B will operate at higher pressure and hence will consume more power

b) leakage loss of the system B will increase due to more header/system pressure

c) Loading time will also be more and hence more unloading power consumption

L-3. List down 10 energy conservation opportunities in pumping systems.

1. **Operate pumps near best efficiency point**
2. **Modify pumping system and pumps losses to minimize throttling**
3. **Adapt to wide load variation with variable speed drives or sequenced control of multiple units**
4. **Use booster pumps for small loads requiring higher pressures**
5. **Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers**
6. **Balance the system to minimize flows and reduce pump power requirements**
7. **Avoid pumping head with a free-fall return (gravity); Use siphon effect to advantage**
8. **Conduct water balance to minimise water consumption**
9. **Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps**
10. **In multiple pump operations, carefully combine the operation of pumps to avoid throttling**
11. **Replace old pumps by energy efficient pumps**

12. **In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation**

13. **Optimise number of stages in multi-stage pump in case of head margins**

14. **Reduce system resistance by pressure drop assessment and pipe size optimisation**

15. **Ensure adequate NPSH at site of installation**

16. **Ensure availability of basic instruments at pumps like pressure gauges, flow meters.**

17. **Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.**

18. **Repair seals and packing to minimize water loss by dripping.**

L-4. In an air conditioning duct of 0.6 m x 0.6 m size, the average velocity of air measured by vane anemometer is 30 m/s. The static pressure at inlet of the fan is 25 mm WC and at the outlet is 35 mm WC. The motor coupled with fan through belt drive draws 19 A at 410 V at a power factor of 0.8. Find out the efficiency of the fan. Assume motor efficiency = 90% and belt transmission efficiency of 98% (density correction can be neglected).

Ans:

Volume flow rate of the fan, Q = Velocity x Area
= 30 x 0.6 x 0.6
= 10.8 m^3/ Sec

Power input to the fan shaft = Motor input power x motor efficiency x transmission efficiency
= ($\sqrt{3}$ x 0.410 x 19 x 0.8 x 0.9 x 0.98)

= 9.52 kW

$$\text{Fan efficiency} = \frac{\text{Volume in } m^3\text{/ Sec x total pressure in mm wc}}{102 \times \text{Power input to the shaft in (kW)}}$$

$$= \frac{10.8 \times 35 - (-25)}{102 \times 9.52} \times 100$$

Fan efficiency = 66.7 %

L -5 An efficiency assessment test was carried out for a standard squirrel cage induction motor in a process plant. The motor specifications are as under.

Motor rated specification: 50 HP/ 415 Volt, 60 Amps, 1475 rpm, 3 phase, delta connected

The following data was collected during the no load test on the motor.

Voltage	= 415 Volts
Current	= 18 Amps
Frequency	= 50 Hz
Stator resistance per phase	= 0.27 Ohms
No load power	= 1080 Watts

Calculate the following:

(i) Iron plus friction and windage losses.
(ii) Stator resistance at 120°C.
(iii) Stator copper loss at operating temperature at 120°C.
(iv) Full load slip and rotor input assuming rotor losses are slip times rotor input.
(v) Motor input assuming that stray losses are 0.5% of the motor rated power.
(vi) Motor full load efficiency and full load power factor.

(i) Let Iron plus friction and windage loss, P_i + fw

No load power, Pnl = 1080 Watts

Stator Copper loss, P st-30^{0}C (Pst.cu)

(This temperature is assumed and hence any temperature used may be given marks)

= 3 × (18 / √3)^2 × 0.27

= 87.49 Watts

Pi + fw = P_{nl} – Pst.cu

= 1080 – 87.49

= 992.51 W

(ii) Stator Resistance at 120^{0}C,

$$R_{120^0C} = 0.27 \times \frac{120 + 235}{30 + 235}$$

= 0.362 ohms per phase

(iii) Stator copper losses at full load, Pst.cu 120^{0}C

= 3 × (60 / √3)^2 × 0.362

= 1303.28 Watts

(iv) Full load slip

S = (1500 – 1475) / 1500

= 0.0167

Rotor input, Pr = P_{output}/ (1-S)

= 37300 / (1-0.0167)

= 37933.49 Watts

(v) Motor full load input power, P input

= P_r + Pst.cu 120^{0}C + (P_i + fw) + P_{stray}

= 37933.49 + 1303.28 + 992.51 + (0.005* × 37300)

= 40415.78 Watts

*where, stray losses = 0.5% of rated output (assumed)

(vi) Motor efficiency at full load

Efficiency = $\frac{P_{output}}{P_{input}} \times 100$

= (37300 / 40415.78) x 100

= 92.3 %

Full Load PF = $\frac{P_{input}}{\sqrt{3} \times V \times I_{fl}}$

= (40415.78 / √3 x 415 x 60)

= 0.937

……. End of Section – III ……

NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY MANAGERS & ENERGY AUDITORS

Question Papers & Model solutions to the Question Papers

PAPER – 3:	**Energy Efficiency in Electrical Utilities**		
Date: 29.05.2005	Timings: 0930-1230 HRS	Duration: 3 HRS	Max. Marks: 150

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **65** 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: OBJECTIVE TYPE

Marks: 50 x 1 = 50

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Put a (√) tick mark in the appropriate box in the answer book

1.	With decrease in design speed of squirrel cage induction motors the required capacitive kVAr for reactive power compensation for the same capacity range will **a) increase** b) decrease c) not change d) none of the above
2.	A six pole induction motor operating at 50 Hz, with 1% slip will run at an actual speed of a) 1000 RPM b) 1010 RPM **c) 990 RPM** d) none of the above
3.	Which of the factors will indicate the performance of a rewound induction motor? a) no load current b) stator winding resistance c) air gap **d) all the above**
4.	Which of the following is not a positive displacement compressor a) Roots blower b) Screw Compressor **c) Centrifugal Compressor** d) Reciprocating Compressor
5.	If voltage applied to a 415 V rated capacitors drops by 5 %, its VAr output drops by about____. a) 5% **b) 10%** c) 19% d) none of the above

6.	The voltage drops in transmission / distribution line depends on ____. a) reactance and resistance of the line b) current in the line c) length of the line **d) all of the above**
7.	Power factor is the ratio of **a) kW/kVA** b) kVA/kW c) kVAr/kW d) kVAr/kVA
8.	If the reactive power drawn by a particular load is zero, it means the load is operating at a) lagging power factor b) leading power factor **c) unity power factor** d) none of the above
9.	Select the ideal location of installing capacitor banks, which will reduce the distribution loss to the maximum extent. a) main sub-station bus bars **b) motor terminals** c) motor control centre d) distribution transformers
10.	A 10 HP/7.5 kW, 415 V, 14.5 A, 1460 RPM, 3 phase rated induction motor, after decoupling from the driven equipment, was found to be drawing 3 A at no load. The current drawn by the motor at no load is high because of a) faulty ammeter reading b) very high supply frequency at the time of no load test c) lose motor terminal connections **d) very poor power factor as the load is almost reactive**
11.	A battery of two reciprocating 250 cfm belt driven compressors installed in a centralized station, were found to be operating at the same loading period of 60% and unloading period of 40%. The least cost solution to reduce wastage of energy in this case would be a) switching off one compressor **b) reducing appropriately the motors pulley sizes** c) reducing appropriately the compressors pulley sizes d) none of the above
12.	Vertical type reciprocating compressor are used in the cfm capacity range of **a) 50-150** b) 200-500 c) 500-1000 d) 1000 and above
13.	Typical acceptable pressure drop in mains header at the farthest point of an industrial compressed air network is a) 0.5 bar b) 1.0 bar **c) 0.3 bar** d) 0.7bar
14.	For every 4°C rise in the air inlet temperature of an air compressor, the power consumption will normally increase by___ percentage points for the same output. **a) 1** b) 2 c) 3 d) 4
15.	The ratio of current drawn by the induction motor to its rated current does not reflect true loading of the motor at partial loads mainly due to a) increased motor slip **b) decreased operating power factor** c) decreased motor efficiency d) none of the above

16.	The efficiency of backward – inclined fans compared to forward curved fans is__ **a) higher** b) lower c) same d) none of the above
17.	Coefficient of Performance (COP) for a refrigeration compressor is given by **a) Cooling effect (kW) / Power input to compressor (kW)** b) Power input to compressor (kW) / cooling effect (kW) c) Q x C_P x (Ti – To) / 3024 d) none of the above
18.	The refrigeration load in TR when 15 m^3/hr of water is cooled from 21^o C to 15 ^{o} C is about a) 32 b) 7.5 **c) 29.8** d) none of the above
19.	With increase in evaporator temperature in a vapor compression refrigeration system, while maintaining a constant condenser temperature, the specific power consumption of the compressor will a) increase **b) decrease** c) sometime increase and sometime decrease d) remains the same
20.	With increase in condensing temperature in a vapor compression refrigeration system, the specific power consumption of the compressor for a constant evaporator temperature will **a) increases** b) decreases c) sometime increases and sometime decreases d) remains the same
21.	Reducing the fan RPM by 10% decreases the fan power requirement by a) 10% **b) 27%** c) 33% d) none of the above
22.	In centrifugal fans, airflow changes direction a) once **b) twice** c) thrice d) none of the above
23.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by a) suction pressure/ (suction pressure + discharge pressure) b) discharge pressure/ (suction pressure + discharge pressure) **c) discharge pressure/ suction pressure** d) suction pressure/ discharge pressure
24.	A 100 cfm reciprocating compressor was observed to be operating at load - unload pressure setting of 6.0 kg/cm^2g and 7.5 kg/cm^2g respectively. This situation will result in a) increased leakage loss in air distribution system b) increased loading timings of the compressor c) increased energy consumption of the compressor **d) all the above**
25.	_____ fans are known as “non-overloading“ because change in static pressure do not over load the motor a) radial b) foreward- curved **c) backward-inclined** d) tube- axial

26.	If inlet and outlet water temperatures of a cooling tower are 42°C and 34°C respectively and atmospheric DBT and WBT are 39 °C and 30 °C respectively, then the approach of cooling tower is a) 3° C **b) 4° C** c) 5° C d) 8° C
27.	The static pressure of a fan running at 500 RPM is 200 mm wc. If it has to be increased to 250 mmwc then the new speed of the fan would be **a) 625 RPM b) 400 RPM c) 1250 RPM d) 750 RPM** **(One mark was awarded to all, as informed by National Certifying Agency)**
28.	Input power to the motor driving a pump is 30 kW. The motor efficiency is 0.9 and pump efficiency is 0.6. The power transmitted to the water is a) 27.0 kW **b) 16.2 kW** c) 18.0 kW d) none of the above
29.	The operating point in a pumping system is identified by a) point of intersection of system curve and efficiency curve b) point of intersection of pump curve and theoretical power curve **c) point of intersection of pump curve and system curve** d) none of the above
30.	It is possible to run pumps in parallel provided their_____ are similar a) suction head b) discharge heads **c) closed valve heads** d) none of the above
31.	Cycles of concentration in circulating water (C.O.C) is the ratio of **a) dissolved solids in circulating water to the dissolved solids in make up water** b) dissolved solids in make up water to the dissolved solids in circulating water c) dissolved solids in evaporated water to the dissolved solids in make up water d) none of the above
32.	Small by-pass lines are installed in pumps some times to _____. a) save energy b) control pump delivery head **c) prevent pump running at zero flow** d) reduce pump power consumption
33.	Which of the following ambient conditions will evaporate minimum amount of water in a cooling tower a) 40°C DBT and 36°C WBT **b) 38 °C DBT and 37 °C WBT** c) 35 °C DBT and 28 °C WBT d) 35 °C DBT and 25 °C WBT
34.	Which one of the following is true to estimate the range of cooling tower? a) Range = Cooling water inlet temperature – Wet bulb temperature b) Range = Cooling water outlet temperature – Wet bulb temperature **c) Range = $\frac{\text{Heat load in kCal/ h}}{\text{Water circulation in liters/ h}}$** d) None of the above
35.	Which one from the following types of cooling towers consumes less power? a) Cross-flow splash fill cooling tower b) Counter flow splash fill cooling tower

	c) Counter flow film fill cooling tower d) None of the above
36.	What is the typical frequency of a high frequency electronic ballast? a) 50 Hz b) 50kHz **c) 30 kHz** d) 60 Hz
37.	If voltage is reduced from 230 V to 190 V for a fluorescent tube light, it will result in a) increased power consumption **b) reduced power consumption** c) increased light levels d) no change in power consumption
38.	Which of the following options reduces the electricity consumption in lighting system in a wide spread plant? **a) installing separate lighting transformer and maintaining optimum voltage** b) maintaining 260 V for the lighting circuit with 220 V rated lamps c) replacing 150 W HPSV lamps with 250 W HPMV lamps d) none of the above
39.	Color rendering index of Halogen lamps compared to low pressure sodium vapor lamps is ___. a) poor **b) excellent** c) average d) very poor
40.	One lux is equal to ___. a) one lumen per ft^2 **b) one lumen per m^2** c) one lumen per m^3 d) none of the above
41.	Which of the following losses is the least in DG sets: a) cooling water loss b) exhaust loss c) frictional loss **d) alternator loss**
42.	In a DG set, the generator is generating 1000 kVA, at 0.7 PF. If the specific fuel consumption of this DG set is 0.25 lts/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour. a) 230 litre b) 250 litre **c) 175 litre** d) none of the above
43.	The main precaution to be taken care by the waste heat recovery device manufacturer to prevent the problem in a DG set during operation is: **a) back pressure** b) turbulence of exhaust gases c) over loading of waste heat recovery tubes d) temperature rise
44.	Lower power factor of a DG set demands_____ a) lower excitation currents **b) higher excitation currents** c) no change in excitation currents d) none of the above
45.	Which combination of readings as indicated by the panel mounted instruments of a DG Set would give the indications of proper capacity utilisation of diesel engine and generator a) kW & Voltage b) kVA & kVAr **c) kW & KVA** d) none of the above

46.	Maximum demand controllers are used to a) control the power factor of the plant b) switch off essential loads in a logical sequence **c) switch off non-essential loads in a logical sequence** d) none of the above
47.	Energy savings potential of variable torque applications compared to constant torque application is: **a) higher** b) lower c) equal d) none of the above
48.	Select the feature which does not apply to energy efficient motors by design: a) starting torque for efficient motors may be lower than for standard motors b) energy efficient motors last longer c) energy efficient motors have low slips which results in speeds about 1% higher than standard motors **d) energy efficient motors have high slips which results in speeds about 1% lower than standard motors**
49.	The basic functions of an electronic ballast fitted to a fluorescent tube light exclude one of the following a) to stabilize the gas discharge b) to ignite the tube light c) to supply power to the lamp at very high frequency **d) to supply power to the lamp at supply frequency**
50.	Slip power recovery system is used in a) DC motor b) synchronous motor c) squirrel cage induction motor **d) slipring induction motor**

……. End of Section – I …….

Section – II: SHORT DESCRIPTIVE QUESTIONS Marks: 10 x 5 = 50

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

S-1. Compute the maximum demand recorded for a plant where the recorded load is as mentioned below in the recording cycle of 30 minutes.

- 500 kVA for 10 minutes
- 300 kVA for 5 minutes
- 50 kVA for 10 minutes
- 400 kVA for 5 minutes

The MD recorder will be computing MD as:

$$\frac{(500 \times 10) + (300 \times 5) + (50 \times 10) + (400 \times 5)}{30} = 300 \text{ kVA}$$

S-2. Briefly explain the impact of power supply quality on the operating performance of induction motors

Motor performance is affected considerably by the quality of input power, that is

- **actual volts and frequency available at motor terminals vis-à-vis rated values**
- **voltage and frequency variations**
- **voltage unbalance across the three phases.**

If voltage supplied is more than rated then (Reverse of below will be the case with under voltage)

1. **Starting torque increases**
2. **% slip reduces**
3. **Full load speed increases**
4. **Efficiency marginally increases at full load but at less than full load the efficiency drops.**
5. **Power factor decreases**
6. **Full load current decreases**
7. **Starting current increases**

If frequency increases (Reverse of below will be the case with under frequency)

1. **Starting torque reduces**
2. **Synchronous speed increases**
3. **Full load speed increases**
4. **Efficiency marginally increases**
5. **Full load current decreases**
6. **Starting current decreases**

S-3 In an engineering industry, while conducting a leakage test in the compressed air system, following data for a reciprocating air compressor was recorded:

Compressor capacity = 50 m^3 per minute
Average load time = 120 seconds
Average unload time = 240 seconds
Find out the leakage quantity in m^3 per day (assume 20 hours per day of operation)

% Leakage in the system

Load time (T) : 120 seconds

Un load time (t) : 240 seconds

% leakage in the system : $\frac{T}{(T+t)} x100$

: 120 /(120 + 240)

: 33.3 %

Leakage quantity : 0.333 x 50

: 16.67 m^3/min X 60 X 20

: 20,000 m^3/ day

S-4 A process fluid at 23m^3/hr. is flowing in a heat exchanger and is to be cooled from 30°C to 25°C. The fluid specific heat is 0.78 kCal/kg. Find out the chilled water flow rate if the chilled water range across the evaporator is 3°C.

Heat transferred from process fluid = 23 x 0.8* x 0.78 x (30 – 25)

= 71.76

Chilled water flow rate = 71.76 / 3

= 23.92 m^3/hr

*** This value was not given in the problem. So this figure may vary. Hence full marks were given if the steps are right (as informed by National Certifying Agency).**

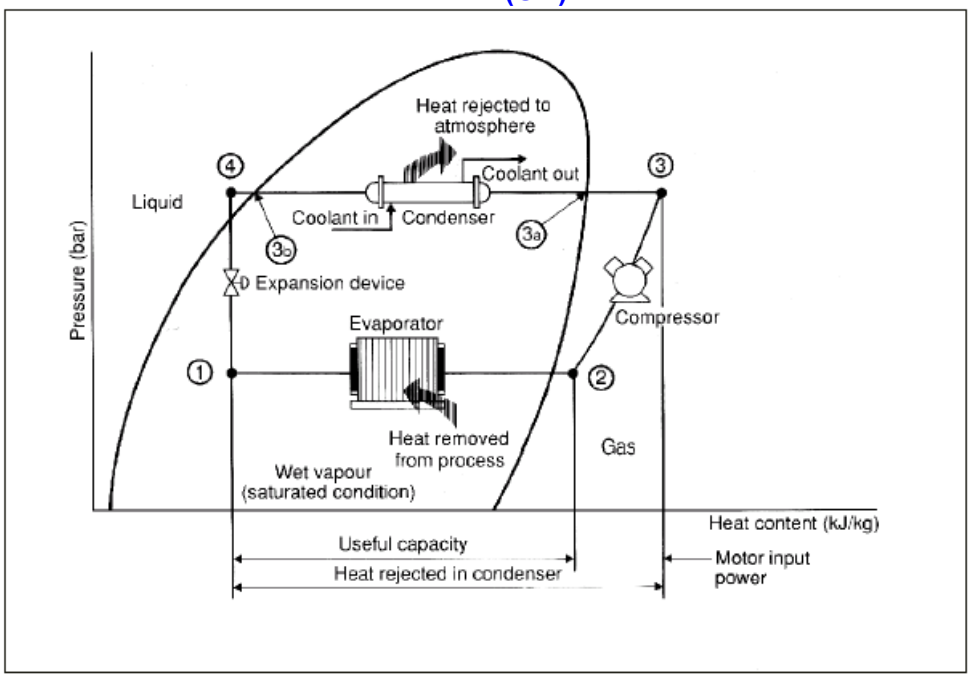
S-5 How the heat is absorbed, or removed from a low temperature source and transferred to a high temperature source in a vapour compression system ?

Vapour Compression Refrigeration

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a

substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source.

(OR)



1 - 2 Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 - 3 The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy put into the compression process is transferred to the refrigerant.

3 - 4 The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) desuperheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 - 1 The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator

S-6 Find out the blow down rate from the following data: Cooling Water Flow Rate is 700 m^3/hr. The operating range is 7^oC. The TDS concentration in circulating water is 1700 ppm and TDS in make up water is 250 ppm.

Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x ($T_1 - T_2$)

= 0.00085 x 1.8 x 700 x 7

= 7.497 m^3/hr

COC = (TDS in circulating water / TDS in make up water)

= 1700 / 250

= 6.8

Blowdown = Evaporation loss / (COC – 1)

= 7.497 / (6.8 – 1)

= 1.293 m^3/hr

S-7 Briefly explain what is meant by daylight linked controls.

Photoelectric cells can be used either simply to switch lighting on and off, or for dimming.

It is however important to incorporate time delays into the control system to avoid repeated rapid switching caused, for example, by fast moving clouds.

By using an internally mounted photoelectric dimming control system, it is possible to ensure that the sum of daylight and electric lighting always reaches the design level by sensing the total light in the controlled area and adjusting the output of the electric lighting accordingly. If daylight alone is able to meet the design requirements, then the electric lighting can be turned off.

S-8. Explain the term Free Air Delivery.

Free Air Delivery is the **capacity of a compressor at the full rated volume of flow of gas compressed and delivered at conditions of total temperature, total pressure, and composition prevailing at the compressor inlet.**

S-9. A centrifugal pump is pumping 80 m^3/hr of water with a discharge head of 5 kg/cm^2 g and a negative suction head of 5 metres. If the power drawn by the motor is 22 kW, find out the pump efficiency. Assume motor efficiency as 90% and water density as 1000 kg/m^3.

Hydraulic power P_h = Q (m^3/s) x Total head, $h_d - h_s$ (m) x ρ (kg/m^3) x g (m/s^2) / 1000

Q = 80/3600 m^3/s , $h_d - h_s$ = 50 – (-5) = 55 m

Hydraulic power P_h = (80/3600) x 55 x 1000 x 9.81 / 1000

= 11.99 kW

Pump shaft power = 22 kW x 0.9

= 19.8 kW

Pump efficiency = hydraulic power / pump shaft power

= 11.99 /19.8

= 60.5 %

S-10. A genset is operating at 700 kW loading with 450^{o}C exhaust gas temperature. The DG set generates 8 kg gas/ kWh generated, and specific heat of gas at 0.25 kCal/ kg ^{o}C. A heat recovery boiler is installed after which the exhaust gas temperature reduces to 190 ^{o}C. How much steam will be generated at 3 kg/ cm^{2} with enthalpy of 650.57 kCal/ kg. Assume boiler feed water temperature as 80^{o}C.

Quantity of flue gas = 700 x 8

= 5600 kg/hr

Heat recovered = 5600 x 0.25 x (450 – 190)

= 3,64,000 kcal/hr

Quantity of steam generated = 3,64,000 / (650.57 – 80)

= 638 kg/hr

……. End of Section - II …….

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 5 x 10 = 50

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

L-1. (a) A 3 phase, 415 V, 75 kW induction motor is drawing 40 kW at a 0.7 PF.

Calculate the capacitor rating requirements at motor terminals for improving PF to 0.95. Also, calculate the reduction in current drawn and kVA reduction, from the point of installation back to the generating side due to the improved PF.

(b) A process plant consumes of 150000 kWh per month at 0.9 Power Factor (PF). What is the percentage reduction in distribution losses per month if PF is improved up to 0.96 at load end?

a) **kVAr Rating = kW [Tan ϕ1 – tan ϕ2]**

Cos ϕ1 = 0.70, ϕ1 = Cos (inv) 0.70 = 45.57, Tan ϕ1 = 1
Cos ϕ2 = 0.95, ϕ2 = Cos (inv) 0.95 = 18.2 , Tan ϕ2 = 0.329

kVAr Rating = 40 kW (1 – 0.329)

= 26.84 kVAr

Current drawn at 0.7 PF = 40 / √3 x 0.415 x 0.7

= 79.5 A

Current drawn at 0.95 PF = 40 / √3 x 0.415 x 0.95

= 58.6 A

Reduction in current drawn = 79.5 – 58.6

= 20.9 A

Initial kVA at 0.7 PF = 40 / 0.7

= 57.1 kVA

kVA at 0.95 PF = 40 / 0.95

= 42.1 kVA

Reduction in kVA = 57.1 – 42.1

= 15 kVA

(OR)

Reduction in kVA = $(\sqrt{3}\ VI)_{old} - (\sqrt{3}\ VI)_{new}$
= (√3 x 0.415 x 79.5) – (√3 x 0.415 x 58.6)
= 57.14 – 42.12
= 15.02 kVA

b) % Reduction in distribution losses = $\left[1 - (PF_1 / PF_2)^2\right]$

= $[1- (0.9/0.96)^2]$

= 0.121

= 12.1 %

L-2. a) A V-belt driven reciprocating instrument air compressor was found to be maintaining a distribution system pressure of 7.5 kg/cm^{2}g. 10% of the instrument air was used for control valves installed in a boiler house and requiring 6.5 kg/cm^{2}g, whereas balance 90% of the instrument air was used for other application requiring 4.5 kg/cm^{2}g. What would you like to advise in this situation?

b) An energy auditor observes the following load unload condition on two similar reciprocating air compressor installed in two separate industrial locations (A & B).

	A	B
Load setting (kg/cm^{2}g)	6.5	6.4
Unload setting (kg/cm^{2}g)	7.5	6.8

The energy auditor concludes that at location A, the compressed air system in operation is inefficient. Do you agree with his observation. Justify your reply with atleast two reasons in support of your argument.

1. **Have a separate small compressor operating at 6.5 to 7 kg/cm^{2}g to meet the boiler house control valve requirement near the boiler house.**

2. **The existing compressor can operate with the pressure setting changed to 4.5 to 5 kg/cm^{2}g**

3. **Since 10 % of the load on the existing compressor is transferred to new compressor and with the reduced pressure setting leakage loss will be less. Now this compressor will be unloading for a longer time. Hence reduce motor pulley size to reduce the RPM thus reducing the output and the unloading time.**

b) Energy auditor is right as

a) system A will operate at higher pressure and hence will consume more power

b) leakage loss of the system A will increase due to more header/system pressure

c) Loading time will also be more and hence more unloading power consumption

L-3. List down 10 energy conservation opportunities in fan systems.

1. **Minimising excess air level in combustion systems to reduce FD fan and ID fan load.**
2. **Minimising air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc.**
3. **Avoid cold air in-leaks which increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnace itself.**
4. **Minimizing system resistance and pressure drops by improvements in duct system**
5. **Adopting inlet guide vanes in place of discharge damper control**
6. **Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmission losses**
7. **Option of two speed motors or variable speed drives for variable duty conditions**
8. **Fan speed reduction by pulley dia modifications for derating**
9. **Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy efficient hollow FRP impeller with aerofoil design, in case of axial flow fans**
10. **Impeller derating (by a smaller dia impeller)**
11. **Change of fan assembly as a whole, by a higher efficiency fan**
12. **Change of impeller by a high efficiency impeller along with cone**

L-4. In an air conditioning duct of 0.6 m x 0.6 m size, the average velocity of air measured by vane anemometer is 35 m/s. The static pressure at inlet of the fan is 20 mm WC and at the outlet is 33 mm WC. The motor coupled with fan through belt drive draws 25 A at 410 V at a power factor of 0.82. Find out the efficiency of the fan. Assume motor efficiency = 89% and belt transmission efficiency of 98% (density correction can be neglected).

Ans:

Volume flow rate of the fan, Q = Velocity x Area
= 35 x 0.6 x 0.6
= 12.6 m^3/ Sec

Power input to the fan shaft = Motor input power x motor efficiency x transmission efficiency
= ($\sqrt{3}$ x 0.410 x 25 x 0.82 x 0.89 x 0.98)
= 12.7 kW

$$\text{Fan efficiency} = \frac{\text{Volume in } m^3\text{/ Sec x total pressure in mm wc}}{102 \times \text{Power input to the shaft in (kW)}}$$

$$= \frac{12.6 \times 33 - (-20) \times 100}{102 \times 12.7}$$

Fan efficiency = 51.55 %

L -5 An efficiency assessment test was carried out for a standard squirrel cage induction motor in a process plant. The motor specifications are as under.

Motor rated specification: 50 HP/ 415 Volt, 60 Amps, 1475 rpm, 3 phase, delta connected

The following data was collected during the no load test on the motor.

Voltage	= 415 Volts
Current	= 20 Amps
Frequency	= 50 Hz
Stator resistance per phase	= 0.275 Ohms
No load power	= 1110 Watts

Calculate the following:

(i) Iron plus friction and windage losses.
(ii) Stator resistance at 120°C.
(iii) Stator copper loss at operating temperature at 120°C.
(iv) Full load slip and rotor input assuming rotor losses are slip times rotor input.
(v) Motor input assuming that stray losses are 0.5% of the motor rated power.
(vi) Motor full load efficiency and full load power factor.

(i) Let Iron plus friction and windage loss, P_i + fw

No load power, Pnl = 1110 Watts

Stator Copper loss, P st-30^{0}C (Pst.cu)

(This temperature is assumed and hence any temperature used may be given marks)

$= 3 \times (20 / \sqrt{3})^2 \times 0.275$

= 110 Watts

Pi + fw = P_{nl} – Pst.cu

= 1110 – 110

= 1000 W

(ii) Stator Resistance at 120^{0}C,

$$R_{120^0C} = 0.275 \times \frac{120 + 235}{30 + 235}$$

= 0.368 ohms per phase

(iii) Stator copper losses at full load, Pst.cu 120^{0}C

$= 3 \times (60 / \sqrt{3})^2 \times 0.368$

= 1324.88 Watts

(iv) Full load slip

S = (1500 – 1475) / 1500

= 0.0167

Rotor input, Pr = P_{output}/ (1-S)
= 37300 / (1-0.0167)
= 37933.49 Watts

(v) Motor full load input power, P input

= P_r + Pst.cu 120^{0}C + (P_i + fw) + P_{stray}

= 37933.49 + 1324.88 + 1000 + (0.005* × 37300)

= 40444.87 Watts

*where, stray losses = 0.5% of rated output (assumed)

(vi) Motor efficiency at full load

Efficiency = $\frac{P_{output}}{P_{input}} \times 100$

= (37300 / 40444.87) x 100

= 92.2 %

Full Load PF = $\frac{P_{input}}{\sqrt{3} \times V \times I_{fl}}$

= (40444.87/ √3 x 415 x 60)

= 0.938

……. End of Section – III ……

NATIONAL CERTIFICATION EXAMINATION 2005

FOR

ENERGY AUDITORS

Question Papers & Model solutions to the Question Papers

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

Date: 29.05.2005 Timings: 1400-1600 HRS Duration: 2 HRS Max. Marks: 100

General instructions:

- *Please check that this question paper contains **4** 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: SHORT DESCRIPTIVE QUESTIONS Marks: 10 x 1 = 10

(i) Answer all **Ten** questions
(ii) Each question carries **One** marks
(iii) Answer should not exceed 50 words

S-1 If the power consumed by a refrigeration compressor is 2 kW per ton of refrigeration, what is the energy efficiency ratio?

$$EER = \frac{12000\ Btu}{2000\ W} = 6$$

S-2 When using a chemical cell oxygen measuring device for stack gas analysis, state the equation to find out the excess air in %?

$$EA = \frac{O_2\%}{21 - O_2\ \%} \times 100\ \%$$

S-3 Which has more energy content, 1 kg of Hydrogen or 1 kg of gasoline?

1 kg of Hydrogen

S-4 Write the overall heat transfer coefficient U, as a function of sensible heat (q_s) and latent heat (q_L).

$$U = (q_s + q_L) / (A \times LMTD)$$

S-5 Which loss is considered the most unreliable or complicated to measure in electric motor efficiency testing?

The stray load loss, because this loss is only estimated and not measured, the method to measure is very complicated and rarely used on the shop floor.

S-6 The inclined manometer connected to a pitot tube is sensing which pressure in a gas stream?

The difference between total and static pressure (also called velocity pressure)

S-7 When using an ultrasonic flow meter for flow measurements in a water pipe which major additional parameter must be guessed or known to calculate the flow in cubic meter per second.

The actual inner diameter to calculate the free cross-sectional area of the pipe.

S-8 What is the correction factor for actual free air discharge in a compressor capacity test if compressed air discharge temperature is 15^0 C higher than ambient air? Assume ambient air = 40^0 C.

Factor is (273 + 40) / (273 + 55) = 0.954

S-9 Which expression to state the energy efficiency of a chiller does not follow the trend "a higher number means a more efficient system"?

The expression "power per ton" (in kW/ton) does not follow the trend. The higher the number the more inefficient the chiller.

S-10 What have all boiler efficiency testing standards in common?

They do not include blow down as a loss in the efficiency determination process.

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

Section - II: LONG DESCRIPTIVE QUESTIONS Marks: 2 x 5 = 10

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

L-1 (i) List any four common losses of boilers and furnaces.

(ii) Which loss is unique to boilers and does not occur in furnaces?

(i) a) radiation losses
b) dry flue gas losses
c) losses due to moisture in the fuel

d) losses due to Hydrogen in the fuel that forms water with Oxygen in the combustion air
e) losses due to partial combustion of Carbon to CO
f) losses due to remaining carbon in the residue (ash)
g) losses due to humidity in the air

(ii) Blow down losses occur only in boilers

L-2 The suction head of a pump is 5 m below the pump centerline. The discharge pressure is 3 kg/cm^2. The flow rate of water is 100 m^3 /hr. Find out the pump efficiency if the actual power input at the shaft is 12 kW.

Discharge Head : 3 kg/cm^2 equals 30 metre head.
Suction Head : - 5 metre.
Total Head : 30 – (-5) = 35 metre.
Hydraulic Power : (100/3600) x 1000 x 9.81 x 35/1000 = 9.54 kW
Pump Efficiency : 100 x 9.54/12 = 79.5%

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

Section - III: Numerical Questions

Marks: 4 x 20 = 80

(i) Answer all **Four** questions
(ii) Each question carries **Twenty** marks

N -1 You as an energy auditor have the task to quickly assess within 20 minutes the technical/ financial performance of a paddy husk fired power plant to be installed.

The plant owner provided you the following information.

- Nominal capacity : 7 MW
- Assumed plant load factor : 0.75
- Number of hours of operation : 8760/ year
- Analysis of paddy husk

Fuel property	Weight %
Moisture	10.79
Mineral Matter	16.73
Carbon	33.95
Hydrogen	5.01
Nitrogen	1.00
Oxygen	32.52
GCV (kCal/kg)	3,568

Provide solutions to the following to the plant owner.

(i) Tonnes of paddy husk to be fired per year if the power plant has an overall efficiency of 25%.

(ii) The area required in square meters to store an inventory of paddy husk 30 cm high for 4 days of operation. Assume paddy husk bulk density of 100 kg/m^3.

(iii) Power plant capital cost is Rs. 28 crores and rice husk cost as delivered is Rs. 1500/ tonnne. Annual repair, maintenance and operation costs are 10% of capital costs. What is the simple pay back period if electricity is sold at Rs.3/kWh.

(i) Paddy husk energy needed per hour $= \frac{860 \text{ kCal} \times 7000 \times 0.75}{0.25}$

=18,060,000 kCal / hour

Tons of husk per hour $= \frac{18,060,000}{1000 \times 3568}$ **= 5.06 tons/hour**

Tons per year 5,06 x 8760 = 44,340 tons/year

(ii) Tons per day: 44,340/365 = 121.48 tons per day or

4 x 121.48 = 486 tons for four days, or

$\frac{486 \text{ tons}}{0.1 \text{ ton/ m}^3} = 4859 \text{ m}^3 = a^2 \times 0.30 \text{ m}$

Area $= 16,197 \text{ m}^2$

(iii) Annual revenue cash flow 7,000 x 8,760 x 0.75 x 3 Rs./kWh = Rs. 137,970,000

Annual R&M cost, 0.1 x Rs.28 crores = Rs. - 28,000,000

Fuel costs 44,340 x 1500 = Rs. - 66,510,000

Annual return = Rs. 43,460,000

Pay back period $= \frac{280,000,000}{43,460,000}$ **= 6.44 years**

N -2 A performance evaluation of a large air fan resulted in the following data.

Pitot tube measurement average velocity pressure	: 75 mm water column
Suction pressure	: - 20 mm water column
Outlet pressure	: 480 mm water column
Area of duct	: 8 square meter
Pitot tube constant	: 0.85
Corrected gas density	: 1.15 kg/ m^3

(i) Calculate flow in m^3/sec.

(ii) Calculate the static fan efficiency based on the following 3 phase motor data.

Line current	:	100 Amps
Line voltage	:	11,000 volts
Power factor of electric motor	:	0.9

Efficiency of motor at the operating load is 95%.

(i) **Flow (v) = Cp x A** $\frac{\text{SQRT (2 x 9.81 x } \Delta P \text{ x } \gamma)}{\gamma}$

Cp = Pitot tube constant
A = Area of duct
ΔP = Pitot tube measurement average velocity pressure
γ = Corrected gas density

Flow (v) = 0.85 x 8 $\frac{\text{SQRT (2 x 9.81 x 75 x 1.15)}}{\text{1.15}}$

Flow (v) = 0.85 x 8 $\frac{\text{SQRT (1692)}}{\text{1.15}}$ **= 243.2 m^3/sec**

(ii) Power input to fan = 1.732 x V x I x Power factor/ 1000
= 1.732 x 11000 x 100 x 0.95/ 1000 = 1628.946 kW
Static fan efficiency = (243.2 x 500) / (102 x 1628.946) = 73.2%

N-3 A multi-storied shopping mall has installed 5 x 110 TR reciprocating compressors of which four compressors are in use and fully loaded for 14 hours per day. The specific power consumption of reciprocating compressor is 0.8 kW/TR. Due to higher energy cost the shopping mall chief engineer has decided to replace reciprocating compressors with screw compressors having specific power consumption of 0.65 kW/TR. The chief engineer needs following input from energy consultant:

(i) Comparison of power and electricity consumption of both reciprocating and screw compressors?

(ii) Annual energy bill savings (for 320 days operation). Present unit cost is Rs 6.00 per kWh

(iii) What should be the size of cooling tower required for proposed screw compressors?

(i) Operating reciprocating compressors capacity : 440 TR

Sp. Power consumption of compressor (reciprocating) : 0.8 kW/TR

Power consumption per hour : 0.8 x 440 = 352 kW

Required screw compressor capacity : 440 TR

Sp. Power consumption of compressor (screw) : 0.65 kW/TR

Power consumption per hour : 286 kW

By replacement of reciprocating compressors with screw compressors reduction in power is 66 kW and in consumption 924 kWh/day.

(ii) **Reduction in power consumption : 66 kW**

Operating hours : 14 per day

Operating days : 320 days per year

Annual energy savings : 66 x 14 x 320

: 2.957 lakh kWh

Annual cost savings : Rs 2.957 x6 = Rs. 17.742 lakh

(iii) **Operating refrigeration load : 440 TR**

Vapour compression type refrigeration systems condenser load (TR) will be around 1.2 time of evaporator load (TR)

Cooling tower capacity : 1.2 x 440 TR

: 528 TR

N-4 (i) What is the total weight of flue gas generated when 20 kg of Methane (CH_4) is burned with 10% excess air?

(ii) How much heat will be recovered from the flue gas by providing an additional water heater if the flue gas is cooled from 300^0 C to 140^0 C?

Additional Information:

Atomic weights C=12, H = 1, O = 16;
specific heat of flue gas = 0.24 kCal/kg^{o}C).
Assume combustion air is 77% Nitrogen (N_2) and 23% Oxygen (O_2) by weight.

$CH_4 + 2O_2 = 2 H_2O + CO_2$

(a) **(12+4) + 2(32) = 2(2+16) + (12+32)**

16 kg of Methane require 64 kg of O_2

20 kg of Methane require $\frac{64}{16}$ = 80 kg of O_2

Therefore, Air (theoretical) required = $\frac{100}{23}$ x 80

= 347.8 kg

Excess Air @ 10% = 34.78 kg

Therefore, 347.8 + 34.78 + 20 = 402.6 kg of stack gas

Or long calculation

CO_2 produced = $\frac{44}{16}$ x20 = 55 kg

H_2O produced = $\frac{36}{16}$ x 20 = 45 kg

Nitrogen (in theoretical air) = $\frac{347.8 \times 77}{100}$ = 267.81 kg.

Total Flue Gas = CO_2 + H_2O + N_2 + Excess Air

= 55+ 45 + 267.81 + 34.78 = 402.6 kg of stack gas

(b) Heat recovered = m cp Δt = 402.6 x 0.24 x (300-140)

= 15,459.8 kCal

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

NATIONAL CERTIFICATION EXAMINATION 2005

FOR

ENERGY AUDITORS

Question Papers & Model solutions to the Question Papers

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

Date: 29.05.2005 Timings: 1400-1600 HRS Duration: 2 HRS Max. Marks: 100

General instructions:

- *Please check that this question paper contains **4** 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: SHORT DESCRIPTIVE QUESTIONS Marks: 10 x 1 = 10

(i) Answer all **Ten** questions
(ii) Each question carries **One** marks

S-1 What have all boiler efficiency testing standards in common?

They do not include blowdown as a loss in the efficiency determination process.

S-2 For which fuel the difference between GCV and LCV will be smaller, Coal or Natural Gas?

Coal

S-3 The overall gas turbine efficiency is defined as η = ?
(Express the equation in units of kW and kWh)

$$\eta = \frac{\text{power output , kW}}{\text{fuel input to gas turbine in kg/h x GCV of fuel in kWh/kg}}$$

In case GCV is expressed in kCal/kg – give ½ mark.

S-4 The more fouling fluid should be on which side of a shell & tube heat exchanger?

Tube side (because it is easier to clean)

S-5 Which loss is considered the most unreliable or complicated to measure in electric motor efficiency testing?

The stray load loss, because this loss is either estimated or not measured, because the method to measure stray load loss is very complicated and rarely used on the shop floor.

S-6 Which pressure is sensed in a gas stream by an inclined manometer connected to a pitot tube?

The difference between total and static pressure also called velocity pressure.

S-7 What would you call, one lumen per square metre?

1 Lux.

S-8 What is the correction factor for actual free air discharge in a compressor capacity test if compressed air temperature is 10^0 C higher than ambient air? (Assume ambient air = 40^0 C)

Factor is (273 + 40) / (273 + 50) = 0.969

S-9 In the performance assessment of a refrigeration system, which performance ratio (energy efficiency) does not follow the trend "a higher ratio means a more efficient refrigeration system"?

The expression "power per ton" (in kW/ton) does not follow the trend. The higher the number the more inefficient the chiller.

S-10 Why does a wind generator produces less power in summer than in winter at the same wind speed?

The wind generator produces less power in summer because the air density in summer is lower due to warmer temperatures. (Or because the air density in winter is higher due to lower temperature)

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

Section - II: LONG DESCRIPTIVE QUESTIONS Marks: 2 x 5 = 10

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

L-1 The suction head of a pump is 5 m below the pump centerline. The discharge pressure is 3 kg/cm^2. The flow rate of water is 100 m^3 /hr. Find out the pump efficiency if the actual power input at the shaft is 15 kW.

Discharge Head	**:**	**3 kg/cm^2 equals 30 metre head.**
Suction Head	**:**	**- 5 metre.**
Total Head	**:**	**30 – (-5) = 35 metre.**
Hydraulic Power	**:**	**(100/3600) x 1000 x 9.81 x 35/1000 = 9.54 kW**

Pump Efficiency : 100 x 9.54/15 = 63.6%

L-2 (i) List any four common losses of boilers and furnaces.

(ii) Which loss is unique to boilers and does not occur in furnaces

(i)
a) radiation losses from the boiler hull
b) dry flue gas losses in the stack gas
c) losses due to moisture in the fuel
d) losses due to Hydrogen in the fuel that forms water by reacting with Oxygen of in the combustion air
e) losses due to incomplete combustion of Carbon to CO
f) losses due to remaining carbon in the residue (ash)
g) losses due to humidity in the air

(ii) Blow down losses occur only in boilers

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

Section - III: Numerical Questions

Marks: 4 x 20 = 80

(i) Answer all **Four** questions
(ii) Each question carries **Twenty** marks

N -1 An energy auditor or energy manager has the task to quickly assess within 20 minutes the technical/ financial performance of a newly installed paddy husk power plant.

The owner of the proposed plant provided the following information.

- Nominal capacity of power plant: 5 MW
- Plant load factor: 0.70
- Analysis of paddy husk, as given below

Fuel property	Weight %
Moisture	10.79
Ash	16.73
Carbon	33.95
Hydrogen	5.01
Nitrogen	1.00
Oxygen	32.52
GCV (kCal/kg)	3,568

What solutions will be provided by the energy auditor to the plant owners on the following.

(i) Tonnes of paddy husk fired per year if the power plant has an efficiency of 25% measured by the direct method.

(ii) The storage area required in square meters to store an inventory of paddy husks 30 cm high for 4 days of operation. Assume paddy husks bulk density of 100 kg/m^3.

(iii) Power plant capital cost is Rs. 20 crore and paddy husks cost as delivered is Rs. 1200/ tonne. Annual repair, maintenance and operation costs are 10% of capital cost. What is the simple pay back period if power is sold at Rs.3/kWh.

(i) Paddy husk energy needed per hour $= \frac{860 \text{ kCal} \times 5000 \times 0.70}{0.25}$

$= 12{,}040{,}000$ kCal / hour

Tons of husk per hour $= \frac{12{,}040{,}000}{1000 \times 3568} = 3.3744$ **tons/hour**

Tons per year $3.3744 \times 8760 =$ 29,560 tons/year

(ii) Tons per day: 29,560/365 = 81 tons per day or

$4 \times 81 = 324$ tons for four days, or

$\frac{324 \text{ tons}}{0.1 \text{ ton}/ m^3} = 3240\ m^3 = a^2 \times 0.30$ m

Area = 10,800 m^2 or about one hectare land

(iii) Annual revenue cash flow $5{,}000 \times 8{,}760 \times 0.7 \times 3$ Rs./kWh = 91,980,000

Annual R&M cost, 0.1 x Rs.20 crores = - 20,000,000

Fuel costs 29,560 x 1200 = Rs. - 35,472,000

Annual return = Rs. 36,508,000

Pay back period = $\frac{200{,}000{,}000}{36{,}508{,}000}$ = 5.478 years

N-2 A 15 kW rated motor burns out. The financial manager of the firm wants to rewind the motor for Rs.3000 to save money. The Energy Manager wants to buy a new premium motor for Rs.20,000/- after selling motor for Rs. 5,000. He claims that he can save much more money in the next five years than the cost difference of the above two options. Other data is as under:

Operating hours/year	= 8000
Rewound motor efficiency	= 89%
New premium motor efficiency	= 93%
Motor loading	= 75%
Power cost	= Rs.4/kWh

(i) How much money does the energy manager actually save over 5 years and what is the simple pay back period ?

(ii) The financial manager claims the financial risk is still too high because operating hours may go down drastically in the next years. How many operating hours/year are required to recover the cost difference within 5 years.

(i) Electricity cost savings over 5 years:

$15 \times 0.75 \left(\frac{100}{89} - \frac{100}{93}\right) \times 8{,}000 \times 4 \times 5 = Rs.86{,}988.$

$\text{Pay back period} = \frac{(20{,}000 - 5{,}000)}{(86988/5)}$

= 0.86 years (or) 10.3 months

(ii) $15 \times 0.75 \left(\frac{100}{89} - \frac{100}{93}\right) \times \text{“Hours”} \times 4 \times 5 = Rs.15{,}000$

“Hours” = 1379 hours per year.

N-3 (i) What is the total weight of flue gas generated when 10 kg of Methane (CH_4) is burned with 10% excess air?

(ii) How much heat will be recovered from the flue gas by providing an additional water heater if the flue gas is cooled from 350^0 C to 210^0 C?

Additional Information:

Atomic weights C=12, H = 1, O = 16;
specific heat of flue gas = 0.24 kcal/kg^{o}C).
Assume combustion air is 77% Nitrogen (N_2) and 23% Oxygen (O_2) by weight.

$CH_4 + 2O_2 = 2H_2O + CO_2$

(a) $(12+4) + 2(32) = 2(2+16) + (12+32)$

16 kg of Methane require 64 kg of O_2

10 kg of Methane require $\frac{64}{16}$ = 40 kg of O_2

Therefore, Air (theoretical) required = $\frac{100}{23} \times 40$

= 173.91 kg.

Excess Air @ 10% = 17.39 kg

Therefore, 173.91 + 17.39 + 10 = 201.3 kg of stack gas

Or long calculation

CO_2 produced = $\frac{44}{16} \times 10 = 27.5$ kg

H_2O produced **= $\frac{36}{16}$ x 10 = 22.5 kg**

Nitrogen (in theoretical air) **= $\frac{173.91 \times 77}{100}$ = 133.91 kg.**

Excess Air **= 17.39 kg.**

Total Flue Gas = CO_2 + H_2O + N_2 + Excess Air

= 27.5 + 22.5 + 133.91 + 17.39 = 201.30 kg of stack gas

(b) Heat recovered = m cp Δt = 201.30 x 0.24 x (350-210)
= 6763.7 kCal

N-4 A multi-storied shopping mall has installed 5 x 110 TR reciprocating compressors of which four compressors are in use and fully loaded for 16 hours per day. Specific power consumption of reciprocating compressor is 0.8 kW/TR. Due to higher energy cost shopping mall chief engineer has decided to replace reciprocating compressors with screw compressors having specific power consumption on 0.65 kW/Tk. Chief engineer need following input from energy consultant.

(i) Comparison of power and electricity consumption of both reciprocating and screw compressors?

(ii) Annual cost savings (for 350 days operation). Present unit cost is Rs 6.50 per kWh, investment for a 220 TR screw compressor is Rs 30 lakh.

(iii) What should be the size of cooling tower required for proposed screw compressors?

(i) **Operating reciprocating compressors capacity : 440 TR**

(If candidates have used 5 x 110 = 550 TR, then 70% of marks can be given)

Sp. Power consumption of compressor (reciprocating) : 0.8 kW/TR

Power consumption per hour : 0.8 x 440 = 352 kW

Required screw compressor capacity : 440 TR

Sp. Power consumption of compressor (screw) : 0.65 kW/TR

Power consumption per hour : 286 kW

By replacement of reciprocating compressors with screw compressors reduction in power is 66 kW per hour and in consumption 1056 kWh/day.

(ii) **Annual cost savings:**

Reduction in power consumption : 66 kW

Operating hours : 16 per day

Operating days : 350 days per year

Annual energy savings : 66 x 16 x 350

: 3.696 lakh kWh

Annual cost savings : Rs 24.024 lakh (@ Rs 6.50 per kWh)

(iii) Cooling tower capacity:

Operating refrigeration load : 440 TR

Vapour compression type refrigeration systems condenser load (TR) will be around 1.2 time of evaporator load (TR)

Cooling tower capacity : 1.2 x 440 TR

: 528 TR

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