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^{0}C - 700^{0}C **b) 850^{0}C - 950^{0}C** c) above 1000^{0}C d) about 500^{0}C
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 / heat in fuel = 0.25

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

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

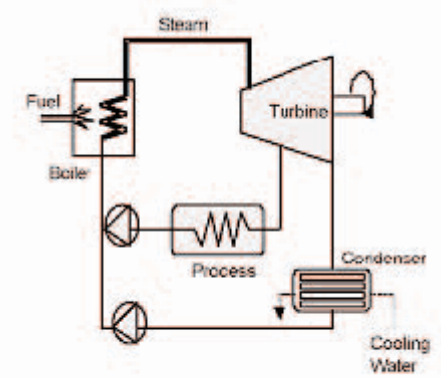
S-7 List advantages of fluidized bed combustion boiler over fixed grate boiler.

(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)

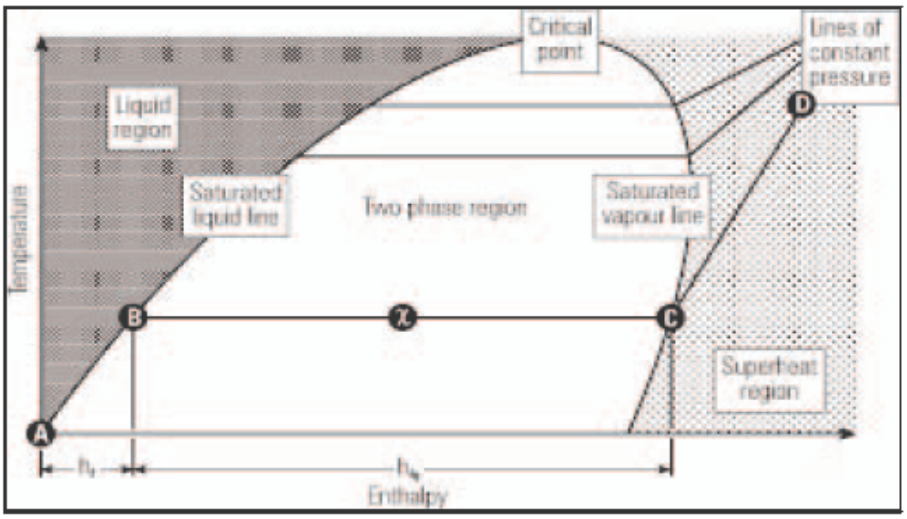


Figure 3.1 Steam Phase Diagram

(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° 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)

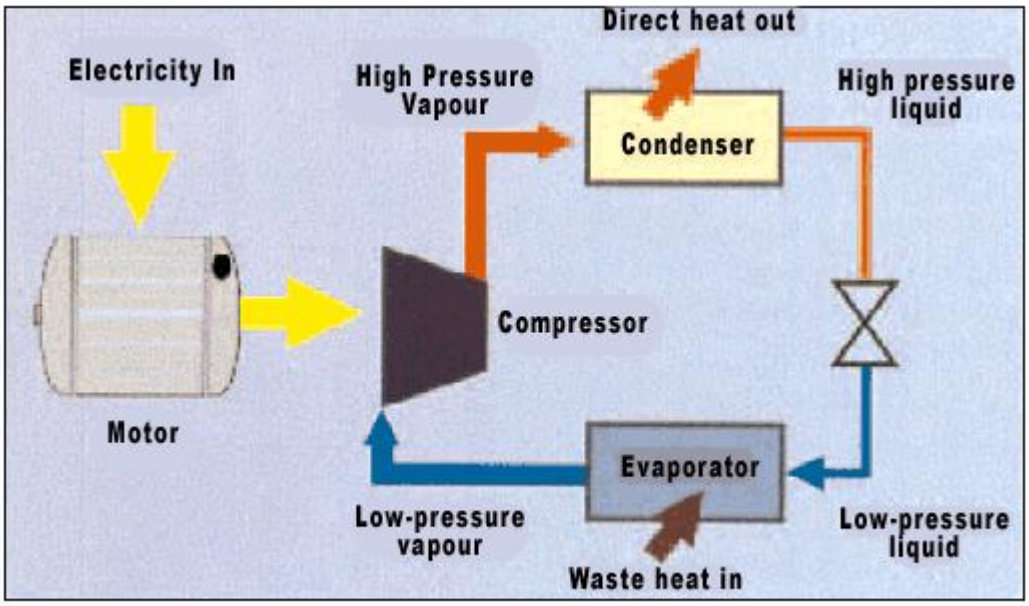


Figure 8.12 Heat Pump Arrangement

(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 ---------