

Regn No: _____

Name: _____

(To be written by the candidates)

**8th NATIONAL CERTIFICATION EXAMINATION – MAY, 2009
FOR
ENERGY MANAGERS & ENERGY AUDITORS**

Paper – 2:	Energy Efficiency in Thermal Utilities		
Date: 23.05.2009	Timings: 1400 to 1700 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 **64** 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) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil, as per instructions

1	The steam generation in a boiler is 16 tonnes for four hours. The oil consumption for the same period is 1.3 Tonnes. The evaporation ratio is a) 12.3 b) 11.5 c) 9.2 d) 14
2	Which of the following heat recovery equipment works on a refrigeration cycle ? a) thermocompressor b) heat wheel c) heat pump d) heat pipe
3	When the furnace is operated below 370°C, then it is called a) muffle furnace b) kiln c) oven d) all the above
4	In a CFBC Boiler the capture and recycling of bed materials is accomplished by a) settling chamber b) cyclone c) back filter d) scrubber
5	One kg of wood contains 20% moisture and 5% Hydrogen by weight. How much water is evaporated during complete combustion of one kg of wood? a) 0.2 kg b) 250 gram c) 0.65 kg d) none of the above

Paper 2 – Set B Key

6	The temperature at which refractory will deform under its own weight is its softening temperature indicated by a) melting point <u>b) PCE</u> c) reform temperature d) critical point
7	In FBC boiler the combustion is carried out at a temperature a) closer to steam temperature b) at adiabatic combustion temperature c) at and above ash fusion temperature <u>d) below ash fusion temperature of fuel used</u>
8	Thermo-compressor is commonly used for a) compressing hot air <u>b) upgrading low pressure steam</u> c) distillation d) reverse compression of CO ₂
9	A rise in conductivity of boiler feed water indicates a) drop in the contamination of feed water b) greater purity of feed water c) <u>rise in the contamination of feed water</u> d) it has got no relation with the contamination of feed water
10	Ceramic fibre gives the maximum savings when used in a) continuous furnace <u>b) batch furnace</u> c) arc furnace d) induction furnace
11	In a low temperature waste heat recovery system, which of the following device is the most suitable a) Economiser <u>b) heat wheels</u> c) regenerator d) ceramic recuperator
12	Which of the following will be the ideal pressure to be maintained in a reheating furnace a) –20 mm <u>b) +1 mm</u> c) +30 mm d) +20 mm
13	Recuperator will be more efficient if the flow path of hot and cold fluids is in: a) co-current mode <u>b) counter current mode</u> c) cross current mode d) none of the above
14	The type of firing used for a pulverized coal fired boiler is a) over firing <u>b) tangential firing</u> c) vertical firing d) mixed firing for effective heat transfer
15	High % of carbon monoxide presence in the flue gas of boiler is an indicator of a) high excess air b) complete combustion c) good control of pollutants <u>d) low excess air</u>
16	The normal velocities encountered in pipes for saturated steam is a) 60 to 80 m/sec b) 10-20 m/sec c) 5 to 10 m/sec <u>d) 30 to 40 m/sec</u>
17	Which is not a property of Ceramic fibre insulation a) low thermal conductivity b) light weight <u>c) high heat storage</u> d) thermal shock resistant

18	The purpose of venting air from steam systems is because air is a a) insulator b) good conductor c) inert substance d) dilutant
19	Reverse osmosis for water treatment involves a) removal of total salts b) removal of only hardness causing salts c) removal of alkali salts d) removal of non-hardness salts
20	In flue gas the theoretical CO ₂ is 15% and the measured CO ₂ is 9% by volume. The % excess air is: a) 66% b) 150% c) 25% d) 20%
21	Which steam trap operates on the principle of difference in density between steam and condensate a) thermodynamic trap b) inverted Bucket c) thermostatic trap d) none of the above
22	Heat transfer rate for drying application will be less if we heat with a) saturated steam b) dry steam c) superheated steam d) high pressure steam
23	“Turndown ratio” for oil fired burner is the ratio of a) air to fuel b) maximum fuel input to actual fuel input c) maximum fuel input over minimum fuel input at same percentage of excess air d) maximum air input over minimum air input
24	An oil fired boiler is operating at 5% O ₂ in the flue gas. The percentage excess air supplied to the boiler is approximately a) 15 % b) 25 % c) 31 % d) 42 %
25	The amount of theoretical air required for complete combustion of one ton of coal as compared to that required for one ton of fuel oil is: a) higher b) lower c) equal d) none of the above
26	What type of steam is generally used for electrical power generation? a) <u>high pressure steam with super heat</u> b) dry saturated steam c) dry saturated steam with high pressure d) wet steam with very high pressure
27	In a furnace, an oxygen rich combustion air (Oxygen – 30% vol. and Nitrogen – 70% vol) is supplied instead of normal air (oxygen – 21% vol. and Nitrogen – 79% vol). By maintaining the other parameters same, the % age of carbon dioxide in the flue gases will be a) same b) lower c) higher d) zero
28	If saturated steam at a pressure of 20 Kg/cm ² (a) is reduced to 10 Kg/cm ² (a), through a pressure reducing valve, the steam will a) condense b) remain saturated c) <u>get superheated</u> d) be a mixture of 50% steam and 50% condensate
29	The major limitation of metallic recuperator is a) handling CO _x , NO _x etc.

	b) reduced life for handling temperature more than 650 °C c) manufacturing difficulty of the required design d) none of the above
30	The unit of specific gravity in SI system is _____ a) N/m³ b) kgf/m³ c) kg/m² d) <u>no unit</u>
31	The minimum capacity of any closed vessel which generates steam under pressure as covered under Indian Boilers Regulation Act is a) 22.75 litres b) 2.275 litres c) 22.75 kilo litres d) 227.5 litres
32	Capillary wick is a part of a) heat pump b) heat wheel c) <u>heat pipe</u> d) regenerator
33	Pick the boiler, which can be considered as most combustion efficient? a) <u>fluidized bed combustion boiler</u> b) lancashire boiler c) stoker fired boiler d) chain grate boiler
34	Which of the following when added to alumino silicate helps to reduce the shrinkage level of ceramic fibre a) <u>Zr O₂</u> b) SiO₂ c) Al₂O₃ d) CaSO₄
35	The difference between mean solid and mean gas velocity in FBC boiler is called a) fluidization factor b) <u>slip velocity</u> c) settling velocity d) none of the above
36	When pure hydrogen is burnt with stoichiometric air, percentage CO₂ on volume basis in flue gas on dry basis will be a) 79% b) 21% c) <u>0%</u> d) 100%
37	When 1 kg of pressurized hot water at 120°C is supplied with 50 kCal of heat at same pressure, its temperature will be a) 220°C b) 190°C c) <u>170°C</u> d) 120°C
38	Controlled wetting of coal (during the coal preparation) would result in a) reduction in flue gas exit temperature b) <u>decrease in the percentage of unburnt carbon</u> c) improper combustion d) increase in the fines of coal
39	The coefficient of thermal expansion of refractory material should be a) <u>low</u> b) high c) medium d) very high
40	The inlet gas temperature in a gas turbine is around a) 1700 °C b) <u>1000 °C</u> c) 650 °C d) 500 °C
41	Oxygen (O₂) percentage measurement by volume basis can be done by using: a) ultrasonic tester b) potassium oxide probe c) copper tubes d) <u>zirconium oxide probe</u>
42	In industrial applications the type of trap used for main steam lines are

Paper 2 – Set B Key

	<u>a) thermodynamic</u> b) thermostatic c) bimetallic d) float
43	Which of the following best indicates the overall efficiency of a Combined Cycle thermal power plant? a) 33 % <u>b) 42 %</u> c) 55% d) 60%
44	Which of the following is used as insulation in low temperature applications ? a) ceramic fibre b) calcium silicate c) fibre glass <u>d) polystyrene</u>
45	The emissivity of ceramic coatings used in furnace a) decreases with increase in temperature <u>b) Increases with increase in temperature</u> c) remains constant irrespective of temperature d) decreases with increase in furnace pressure
46	The percentage raise in boiler efficiency by a 20 °C raise in combustion air temperature is a) 0.1% b) 0.2% c) 10% <u>d) 1%</u>
47	Instrument used for measuring temperature in a glass furnace is a) Leaf type thermocouple <u>b) Infrared pyrometer</u> c) Pt/Pt-Rh thermocouple with indicator d) Chrome alumnel thermocouple with indicator
48	The percentage efficiency of a reheating furnace, operating at 10 tonnes per hour and consuming furnace oil of 230 kg/hour for reheating the material from 40 °C to 1100 °C (specific heat of material is 0.13 kCal / kg °C and calorific value of furnace oil is 10,000 kCal /kg) is <u>a) 60</u> b) 70 c) 80 d) 50
49	The percentage of energy consumed by air compressor in gas turbine plants is typically a) 10% b) 22% <u>c) 55%</u> d) 80%
50	Which of the following is not required in the boiler efficiency evaluation by direct method a) steam flow b) fuel flow c) feed water temperature <u>d) O₂ % in flue gas</u>

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

Section - II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

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

S-1 Given the choice would you paint the outer surface of a reheating furnace black, or with a shiny glossy colour (such as silver colour)? Explain.

Ans:

The emissivity of the outer surface should be kept to a minimum since the skin losses would increase with high emissivity. A black colour acts like a black body with highest emissivity, while a glossy and shiny aluminium foil has about the lowest emissivity. Therefore, radiation loss is minimized. Shiny glossy colour, which has a lower emissivity should be used.

S-2 A 5 MW DG Set is operating at 70% load. A waste heat recovery boiler is installed to recover heat from exhaust gas to generate steam at 10 kg/cm². Find out the quantity of steam generated annually after installing the waste heat recovery boiler

Given Data:

- Flue gas exit temperature := 500 °C
- Flue gas temperature after Waste heat recovery boiler := 250 °C
- Specific heat of flue gases = 0.25 kCal/kg/°C
- Specific gravity of diesel oil = 0.85
- Air to fuel ratio = 30 kg/kg
- Specific fuel consumption = 4 kWh/liter
- Enthalpy of steam at 10 kg/cm² = 660 kCal/kg
- Feed water temperature = 30 °C
- Operating hours per year = 8000 hrs

Solution:

Average load of DG set = $5 \times 0.7 = 3.5$ MW or 3500 kW

Diesel consumption = $3500 \times 0.85 / 4 = 744$ kg/hr

Heat available for WHR boiler = $744 \times 30 \times 0.25 (500 - 250) = 1395000$ kCal/hr

Steam generation at 10 kg/cm² = $1395000 / (660 - 30) = 2214$ kg/hr or 2.2 tons/hr

Annual steam generation = $2.2 \times 8000 = 17,600$ tons /year.

S-3 Calculate pressure drop in meters when pipe diameter is increased from 250 mm to 350 mm for a length of 1000 meters. Water velocity is 2 m/s in the 250 mm diameter pipe, and friction factor is 0.005..

Ans. Pressure drop = $\frac{4fLV^2}{2gD}$

Pressure drop with 250 mm = $4 \times 0.005 \times 1000 \times 2^2 / (2 \times 9.81 \times 0.250)$
= 16.30 m

Velocity of water in pipe of 350 mm diameter = $(0.25 \times 0.25 \times 2) / (0.35 \times 0.35) = 1.02$ m/s

Pressure drop with 350 mm = $4 \times 0.005 \times 1000 \times 1.02^2 / (2 \times 9.81 \times 0.350)$
= 3.02 m

Pressure drop reduction = $16.30 - 3.02 = 13.28$ m

S-4 The evaporation ratio of a coal fired boiler is 5. Estimate boiler efficiency if steam enthalpy is 650 kcal/kg; feed water temperature is 65°C and Calorific Value of coal is 4000 kcal/kg.

Ans :

Boiler efficiency = output/input * 100

Boiler efficiency = $100 \times Q (H-h) / (q \times GCV)$

= $\frac{5 \times (650-65) \times 100}{1 \times 4000} = \underline{73.13 \%}$

S-5 Explain the difference between Flash Point and Pour Point of a liquid fuel?

Ans:

Flash Point

The flash point of a fuel is the lowest temperature at which the fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it.

Pour Point

The pour point of a fuel is the lowest temperature at which it will pour or flow when cooled under prescribed conditions. It is a very rough indication of the lowest temperature at which fuel oil is readily pumpable.

S-6 What is the significance of volatile matters in case of solid fuels being used for combustion?

Ans :

Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in coal. Thus the volatile matter is an index of the gaseous fuels present. Typical range of volatile matter is 20 to 35%.

Volatile Matter

- Proportionately increases flame length, and helps in easier ignition of coal.
- Sets minimum limit on the furnace height and volume.
- Influences secondary air requirement and distribution aspects.
- Influences secondary oil support

S-7 What is the major advantage of a self recuperative burner (SRB). For a SRB the quantity of heat brought in by pre heated air is 2000 kCal/kg fuel and the quantity of heat taken away by exhaust gases is 4000 kCal per kg fuel. If the calorific value of the fuel is 10,000 kCal/kg, find the % fuel saving rate?

Ans:

Self Recuperative Burners

Self-recuperative burners (SRBs) are based on traditional heat recovery techniques in that the products of combustion are drawn through a concentric tube recuperator around the burner body and used to pre-heat the combustion air

A major advantage of this type of system is that it can be retro-fitted to an existing furnace structure to increase production capability without having to alter the existing exhaust gas ducting arrangements. SRBs are generally more suited to heat treatment furnaces where exhaust gas temperatures are lower and there are no stock recuperation facilities.

Estimation of fuel savings

By using preheated air for combustion, fuel can be saved. The fuel saving rate is given by the following formula:

$$S = P \times 100 / (F + P - Q)$$

where S: fuel saving rate, %

F: Calorific value of fuel (kCal/kg fuel)

P: quantity of heat brought in by preheated air (kCal/kg fuel)

Q: quantity of heat taken away by exhaust gas (kCal/kg fuel)

$$S = 2000 \times 100 / (10000 + 2000 - 4000)$$

$$S = 12.5 \%$$

S-8 What is clinker? List four factors which lead to clinker formation in case of stationary grate coal fired boiler.

Clinker is a mass of rough, hard, slag-like material formed during combustion of coal due to low fusion temperature of ash present in coal. Presence of silica, calcium oxide, magnesium oxides etc. in ash lead to a low fusion temperature.

Factors leading to clinker formation are :

- Low ash fusion temperature
- Uneven size or more fines in coal
- Combustion without raking the coal bed
- Pre heated air used for combustion

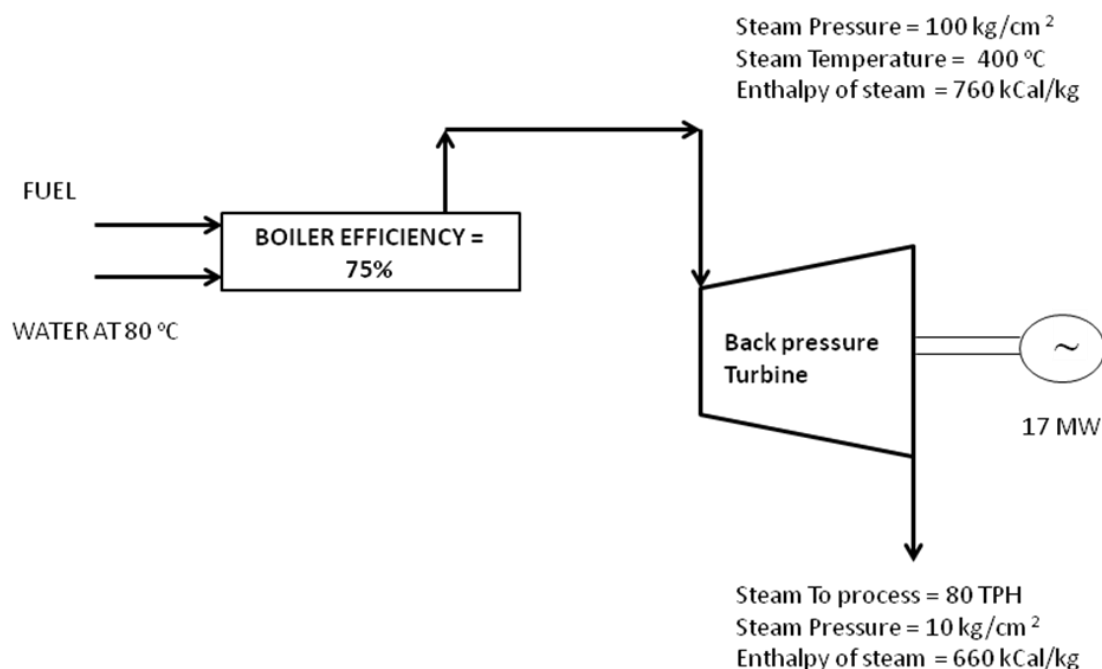
----- End of Section – II -----

Section - III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

- (i) Answer all Six questions
- (ii) Each question carries Ten marks

L-1 Calculate the steam generation requirement and fuel oil consumption for the co-generation scheme depicted below



Assumption = Losses across turbine including steam loss = 3 million kCal/hr
GCV of fuel oil = 10,000 kCal/hr

Solution:

$$\text{Heat in process steam} = 80 \times 1000 \times 660 = 52.8 \times 10^6 \text{ kCal/hr}$$

$$\text{Heat equivalent to power generation} = 17 \times 1000 \times 860 = 14.62 \times 10^6 \text{ kCal/hr}$$

$$\text{Heat loss across turbine} = 3 \times 10^6 \text{ kCal/hr}$$

$$\text{Total Heat input to turbine} = (52.8 + 14.62 + 3) \times 10^6 \text{ kCal/hr} = 70.42 \times 10^6 \text{ kCal/hr}$$

$$\begin{aligned} \text{Equivalent steam generation at } 100 \text{ kg/cm}^2 \text{ at } 760 \text{ kCal/kg} &= 70.42 \times 10^6 / 760 \\ &= 92.7 \text{ tons/hr} \end{aligned}$$

$$\text{Fuel Oil Consumption at 75\% efficiency} = [92.7 (760 - 80)] / (0.75 \times 10000) \\ = 8.40 \text{ tons/hr}$$

L-2 In an engineering industry, resistance heating type furnace was used for heat treatment of the product. The power consumption of the furnace at 1/3 load and full load is 860 kWh and 1600 kWh per cycle respectively. The furnace heat treatment cycle and loading of the furnace was analysed. The details are as follows:

Furnace capacity : 180 kW
Loading capacity of furnace : 10 Tonnes
Heat treatment cycle : Heating up to 650 °C – 6 hours
: Soaking at 650 °C – 8 hours
: Cooling in furnace – 4 hours
Quantity of the stock to be treated : 1500T/year
Evaluate the energy savings by optimum (full loading) loading?

Solution Sp. Power consumption of stock:
Load in furnace (1/3) = $10 \times 1/3$
= 3.3 MT

Power consumption for 1/3rd load = 860 kWh/cycle

Sp. Power consumption at 1/3rd load = $860/3.3$
= 260.6 kWh/MT

Load in the furnace (full) = 10 MT
Power consumption at full load = 1600 kWh/cycle
Sp. Power consumption at full load = $1600/10$
= 160 kWh/MT

Reduction in power consumption at optimum load (full load)
= $260.6 - 160$
= 100.6 kWh/MT

Annual stock production = 1000 T

By operating furnace with each batch of 10T (full load)
Reduction in power consumption = 1500×100.6
= 150900 kWh /year

L-3 Analyse the diagram as given below and calculate:

1. Boiler Efficiency by direct method
2. Water Temperature in the condensate tank

3. Estimate fuel loss due to the drop in feed water temperature, assuming the boiler efficiency to be the same

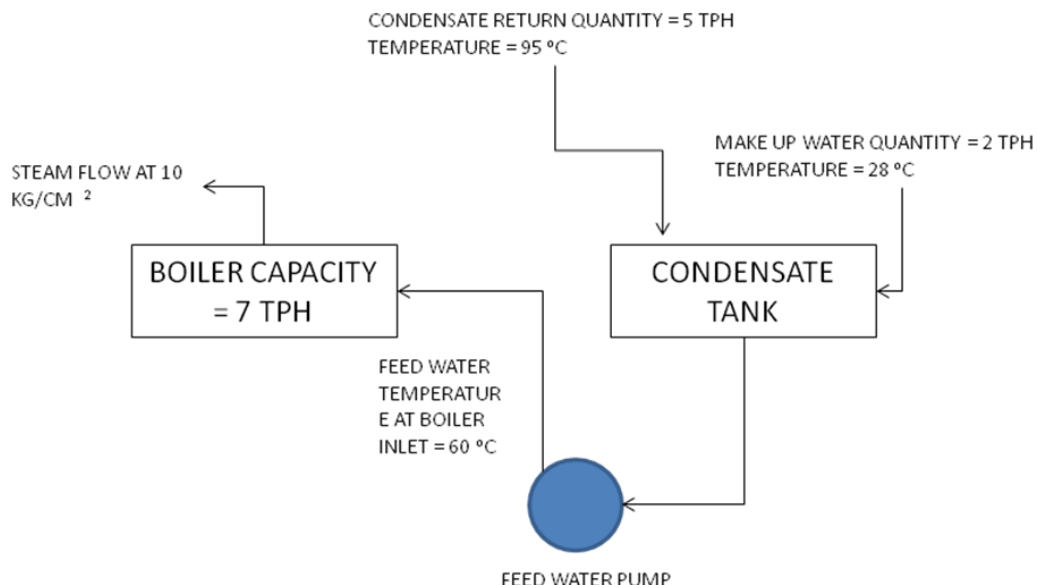
Given that:

Enthalpy of steam at 10kg/cm² = 665 kCal/kg

Furnace Oil consumption = 600 liters/hr

Specific Gravity of furnace oil = 0.89

G.C.V. of furnace oil = 10,000 kCal/kg



Solution : Oil Consumption = 600 x 0.89 = 534 kg/hr

$$1) \text{ Boiler Efficiency} = \frac{7000 (665 - 60) \times 100}{534 \times 10000} = 79.3 \%$$

2) Feed water temperature in condensate tank

$$= \frac{[5000 \times 95 + 2000 \times 28]}{7000} = 76^{\circ}\text{C}$$

$$3) \text{ Fuel Loss} = \frac{[7000 \times (76 - 60)]}{10000 \times 0.793} = 14 \text{ kg/hr}$$

L-4 A textile plant has an extensive network and the steam condensate is not being recovered. The plant management is planning to recover the condensate and generate flash steam for use as low pressure process steam for fuel economy. The following are the parameters about the system.

Condensate quantity	1000 kg/hr
Condensate Pressure	10 bar
Cost of steam	Rs 1100/ T
Annual operating hours	6000

Low pressure process steam (flash steam) pressure	2 bar
Sensible heat of condensate at 10 bar	188 kCal/kg
Sensible heat of condensate at 2 bar	135 kCal/kg
Latent heat of steam at 2 bar	518 kCal/kg
Boiler Efficiency	80 %
GCV of fuel oil	10,200 kCal/kg
Specific Gravity of fuel oil	0.92
Condensate temperature when recovered	95 °C
Make up water temperature	35 °C

Calculate the Quantity of flash steam which can be recovered, and the annual fuel oil savings on account of condensate recovery

Solution :

a) Flash steam available % = $S1 - S2 / (L2)$

Where: S1 is the sensible heat of higher pressure condensate.

S2 is the sensible heat of the steam at lower pressure

L2 is the latent heat of flash steam (at lower pressure).

% of Flash steam recoverable = $(188 - 135) / 518 = 10.2 \%$

Quantity of flash steam recovered from condensate = $1000 \times 0.102 = 102 \text{ kg/hr}$

Condensate available for recovery after flash steam = $1000 - 102 = 898 \text{ kg/hr}$

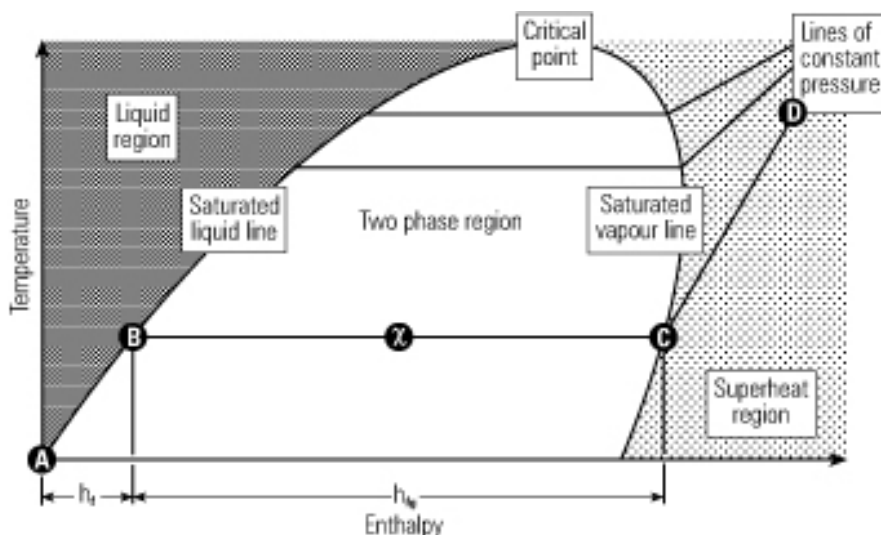
Heat recovered = $898 \times (95 - 35) = 53880 \text{ kCal/hr}$

Oil saved = $53880 \times 6000 / (0.80 \times 10200) = 39.62 \text{ tons/yr}$

L-5 What is a steam phase diagram? Draw the steam phase diagram and mark the following:

- Critical Point
- Two phase region
- Saturated liquid line
- Saturated vapor line
- Lines of constant pressure
- Super heated region
- Liquid region

Solution: The relationship between the enthalpy and the temperature at various different pressures, is known as a phase diagram



L-6 A pulp and paper industry has a conventional stoker fired water tube boiler. In view of the poor quality of coal being received the company decides to retrofit the existing boiler with a fluidized bed coal fired combustion systems. What would be the important aspects to be considered in the retrofit project. Also list down categorically four changes to be incorporated ?

Solution Retrofitting fluidized bed coal fired combustion systems to conventional boilers have been carried out successfully both in India and abroad. The important aspects to be considered in retrofit projects are:

- Water/steam circulation design
- Furnace bottom-grate clearance
- Type of particulate control device
- Fan capacity
- Availability of space.

Retrofitting of a fluidized bed combustor to a conventional stoker fired water tube boiler may involve:

- The replacement of grate by a distributor plate with short stand pipes for admitting air from the wind box located underneath.
- Installation of stand pipes to remove ash from the bed.
- Provision of horizontal hair pin tubes in the bed with a pump for forced circulation from the boiler drum.
- Modification of crusher to size the coal/limestone mixture for pneumatic under bed injection of the mixture.

It may be emphasized that conversion of a conventional coal fired system to a fluidized bed combustion system can be accomplished without effecting major changes, after making a cost-benefit analysis. Oil fired boilers can also be converted to coal fired fluidized bed combustion systems.

----- **End of Section – III** -----