

Regn No: _____

Name: _____

(To be written by the candidate)

11th NATIONAL CERTIFICATION EXAMINATION – February, 2011 FOR ENERGY MANAGERS & ENERGY AUDITORS

PAPER – 2: Energy Efficiency in Thermal Utilities

Date: 05.02.2011 Timings: 1400-1700 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- Please check that this question paper contains **13** 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.	Liquid fuel density is measured by an instrument called a) tachometer <u>b) hydrometer</u> c) anemometer d) none of the above
2.	When the liquid LPG evaporates the volume of gas occupied will be about a) 25 times <u>b) 250 times</u> c) 100 times d) None of the above
3.	The air to natural gas (stoichiometric) ratio, by volume, for complete combustion varies between a) 14:1 to 15:1 b) 7:1 to 8:1 <u>c) 9.5:1 to 10:1</u> d) None of the above
4.	The draft caused solely by the difference in weight between the column of hot gas inside the chimney and column of outside air is known as; a) balanced draft b) induced draft c) forced draft <u>d) natural draft</u>
5.	The type of boiler in which water passes through the tubes and hot gases pass outside the tubes is known as;

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	<u>a) water tube</u>	b) fire tube	c) packaged boiler	d) none of the above
6.	CO ₂ percentage (by volume) measurement in flue gases can be done by using;			
	a) ultrasonic probe	b) potassium oxide probe		
	<u>c) portable fyrite</u>	d) zirconium oxide probe		
7.	For optimum combustion of fuel oil, O ₂ percentage in flue gases should be maintained at;			
	<u>a) 2-3%</u>	b) 14-15%	c) 21-23%	d) none of the above
8.	The mode of heat transfer from hot body to cold body without a conveying medium is;			
	a) conduction	<u>b) radiation</u>	c) convection	d) none of the above
9.	A recuperator in a furnace is used to extract heat from flue gases for preheating;			
	a) the charge	b) fuel oil	<u>c) air for combustion of fuel</u>	d) feed water
10.	In a Mollier diagram, the point at which the saturated liquid and saturated vapour lines meet is known as the;			
	a) vapour point	b) liquid point	<u>c) critical point</u>	d) sub-critical point
11.	The steam pressure drop in a steam pipe is inversely proportional to the _____ of pipe diameter			
	a) 4 th power	b) 6 th power	<u>c) 5th power</u>	d) none of above
12.	The best quality of steam for indirect process heating is;			
	<u>a) dry saturated steam</u>	b) super heated steam	c) wet steam	d) super critical steam
13.	The emissivity of conventional refractories used in a furnace;			
	a) increases with increase in temperature	<u>b) decreases with increase in temperature</u>		
	c) remains constant	d) decreases with increase in furnace pressure		
14.	The main constituent of natural gas, accounting for about 95% of the total volume, is;			
	<u>a) methane</u>	b) iso-octane	c) propane	d) hexane
15.	Steam generated in a boiler is 36 tonnes in 3 hours. Fuel consumption in the same period is 1 tonne per hour. Continuous blow down is 8% of feed water input. The boiler evaporation ratio is;			
	<u>a) 12</u>	b) 11.7	c) 36	d) 24
16.	Heat loss through furnace openings is directly proportional to;			
	a) fourth power of furnace temperature	<u>b) fourth power of absolute furnace temperature</u>		
	c) absolute furnace temperature	d) square of absolute furnace temperature		
17.	A power generation system which uses first a gas turbine followed by a steam turbine is called;			
	a) topping cycle	<u>b) combined cycle</u>	c) Brayton cycle	d) bottoming cycle
18.	Magnesite, chrome magnesite and dolomite are _____ type of refractory;			
	a) acidic	<u>b) basic</u>	c) neutral	d) none of the above
19.	In a steam system, the purpose of venting air is because air is a;			
	a) good conductor	b) inert substance	c) dilutant	<u>d) insulator</u>

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20.	Latent heat at the critical point of a steam phase diagram is; a) 640 kCal/kg <u>b) zero</u> c) 540 kCal/kg d) 584 kCal/kg
21.	What is the most effective way to avoid ambient air infiltration into a fuel fired furnace; a) slight negative pressure should be maintained b) operate at about 90% capacity c) increase the chimney height <u>d) slight positive furnace pressure should be maintained</u>
22.	Which loss is the highest in a typical forging furnace operating at 1300 °C? <u>a) flue gas loss</u> b) wall loss c) cooling water loss d) unavoidable opening loss
23.	Scale losses in a reheating furnace will; a) increase with CO in combustion gases <u>b) increase with excess air</u> c) have no relation with excess air d) decrease with excess air
24.	Molecular weight of SO ₂ in kg/kg mole is; a) 34 <u>b) 32</u> c) 12 d) 44
25.	A process plant needs 4 bar and 15 bar steam in addition to electric power. The most suitable co-generation option for this process plant among the following, will be; <u>a) extraction cum back pressure turbine</u> b) back pressure turbine c) condensing turbine d) none of the above
26.	Proximate analysis of a fuel is determination of a) carbon, hydrogen, nitrogen, sulphur, moisture <u>b) Fixed carbon, ash, volatile matter and moisture</u> c) higher calorific value d) lower calorific value
27.	Suitable atomizing viscosity of furnace oil (100 Redwood seconds-1) for use in LAP/MAP burners requires an oil preheating temperature of about; a) 80 °C <u>b) 105 °C</u> c) 125 °C d) 135 °C
28.	With increase in the percentage of excess air for combustion of coal, percentage of CO ₂ in flue gas. a) increases <u>b) decreases</u> c) remains same d) none of the above
29.	The presence of Calcium and Magnesium Bicarbonates in boiler feed water would form: a) acidic solution <u>b) alkaline solution</u> c) neutral solution d) none of the above
30.	F & A (from and at) rating of the boiler is the amount of steam generated from; a) water at 0 °C to saturated steam at 100 °C b) water at feed water temperature to saturated steam at 100 °C <u>c) water at 100 °C to saturated steam at 100 °C</u> d) water at ambient temperature to saturated steam at 100 °C
31.	Condensate, at pressure of 4 kg/cm ² and 160 °C temperature, when exposed to atmosphere will; a) fully convert into flash steam <u>b) partially convert into flash steam</u> c) remain as condensate d) immediately cool down to ambient temperature
32.	The lowest level of excess air is required in a;

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	a) coal burner c) <u>high pressure gas burner</u>	b) low pressure oil burner d) high pressure oil burner
33.	Velocity of steam in steam pipe is directly proportional to;	
	a) number of bends in pipe c) length of pipe	b) <u>specific volume of steam</u> d) diameter of the pipe
34.	As the pressure of steam increases from 4 kg/cm ² to 8 kg/cm ² , the value of total enthalpy and latent heat of steam respectively;	
	a) increases & remains the same c) decreases & increases	b) <u>increases & decreases</u> d) decreases & remains the same
35.	The difference in temperature between steam and condensate refers to the principle of operation of a;	
	a) thermodynamic trap b) <u>thermostatic trap</u>	c) orifice type trap d) float trap
36.	Pinch analysis uses the _____ law of Thermodynamics	
	a) first b) <u>second</u>	c) third d) both first & second
37.	Which of the following is not a property of ceramic fibre insulation?	
	a) low thermal conductivity c) <u>high heat capacity</u>	b) light weight d) thermal shock resistant
38.	The working media in a thermocompressor is	
	a) electricity b) compressed air c) high temperature oil	d) <u>steam</u>
39.	The turbine heat rate is expressed as	
	a) kWh/kCal b) kg/kCal c) <u>kCal/kWh</u>	d) none of the above
40.	Auxiliary power consumption for coal preparation will be highest in a;	
	a) stoker fired boiler b) AFBC boiler c) CFBC boiler	d) <u>pulverized coal fired boiler</u>
41.	In a heat exchanger, for the same heat duty, higher the heat transfer coefficient;	
	a) higher will be the heat transfer area needed c) <u>lower will be the heat transfer area needed</u>	b) higher will be the LMTD d) lower will be the LMTD
42.	Correction factor for LMTD is commonly applicable for;	
	a) parallel flow type b) counter flow type c) <u>cross flow type</u>	d) both (a) and (b)
43.	Alumina is a type of refractory.	
	a) acid b) basic c) <u>neutral</u>	d) none of the above
44.	Which of the following does not contribute to steam savings	
	a) insulation of steam pipe lines c) providing dry steam for process	b) <u>superheated steam for indirect process heating</u> d) none of the above
45.	Which of the following fuel requires maximum air for stoichiometric combustion?	
	a) butane b) propane c) <u>hydrogen</u>	d) coal

Paper 2 –Set A Solutions

46.	In a cogeneration system, with extraction condensing turbine, the highest heat rate is recorded when; a) <u>maximum power output and maximum extraction to process</u> b) maximum power output and normal extraction to process c) maximum power output and minimum extraction to process d) none of the above
47.	A bottoming cycle is one in which fuel is used for producing a) power primarily followed by byproduct heat output b) <u>heat primarily followed by byproduct power output</u> c) power, heat and refrigeration simultaneously d) none of the above
48.	In a reheating furnace, soaking time of a cycle depends typically on; a) excess air level b) preheat temperature of charge c) <u>thickness of the charged material</u> d) furnace atmosphere
49.	A supercritical boiler has parameters beyond critical point which refers to; a) <u>221.2 bar (a) pressure and 374.18 °C temperature</u> b) 246 bar (a) pressure and 538 °C temperature c) 306 bar (a) pressure and 598 °C temperature d) 170 bar (a) pressure and 538 °C temperature
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) <u>rise in the total dissolved solids in boiler water</u> d) greater purity of feed water

..... **End of Section – I**

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General instructions:

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Section – II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

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

S-1 Briefly explain the working of a thermic fluid heater and its advantages over steam heating system

Ans

In thermic fluid heaters, a specific type of oil synthetic/mineral is used as heat carrier. This fluid can be heated upto 300°C at atmospheric pressure. In comparison steam would require a pressure of 85 bars to obtain this temperature.

The heaters are made with coils of seamless tubes. The thermal fluid is heated during the flow through the tubes. The heat is transferred to the fluid as radiant heat in the combustion chamber, where the inner cylindrical tube coil and a flat tube coil form the chamber wall and the bottom respectively. The hot thermic fluid is circulated to various process equipments such as dryers, heaters, deodouriser etc. where it gives up the heat. The return oil at a temperature 10 to 20 °C less comes back to the thermic fluid heater to get heated up again. The circulation is carried out by a thermic fluid circulation pump.

The thermic fluid heater operates between two temperature ranges. Once the upper limit is reached the burner is switched OFF or goes into the low fire mode. In the case of solid fuel fired system the ID fan switches OFF on reaching the upper limit. When the temperature reaches the lower limit due to heat transfer in the process, the burners come ON again and in case of solid fuels, the ID fan comes ON again.

There are several advantages in using thermic fluids compared to steam systems. The most obvious advantages are as follows

- *High temperature operation at atmospheric pressure*

- *Optional temperature level set points*
- *No supply of treated water and hence no heat loss due to condensate flash steam*
- *No risk of corrosion*
- *Easy to operate*

S-2 A boiler generates steam at the rate of 20 tonnes/hr consuming 4 ton/hr of coal having a gross calorific value of 4200 kCal/kg. Calculate the evaporation ratio and efficiency of the boiler if the enthalpy of the generated steam is 650 kCal/kg and feed water temperature is 60 °C.

Ans:

Evaporation ratio means kilogram steam generated for kilogram of fuel consumed.

$$\text{Evaporation ratio} = (20/4) = 5$$

$$\begin{aligned}\text{Efficiency of the boiler} &= \frac{20 \times 1000 \times (650 - 60) \times 100}{4 \times 1000 \times 4200} \\ &= 70.23\%\end{aligned}$$

S-3 List down five energy conservation measures in steam system

Ans:

- Fix steam leaks and condensate leaks.
- Use back pressure steam turbines to produce lower steam pressures.
- Use dry steam for indirect process heating.
- Ensure process temperatures are correctly controlled.
- Maintain lowest acceptable process steam pressures.
- Remove or blank off all redundant steam piping.
- Ensure condensate is returned or re-used in the process.
- Preheat boiler feed-water.
- Recover boiler blowdown.
- Check operation of steam traps.
- Remove air from indirect steam using equipment
- Inspect steam traps regularly and repair malfunctioning traps promptly.
- Consider recovery of flash steam
- Use waste steam for water heating.
- Reduce work done by steam
- ANY OTHER RELEVANT POINT

S-4 The efficiency of a boiler on GCV basis is 85%. The fuel contains 1% moisture and 12% hydrogen. The GCV of fuel is 10,500 kCal/kg. What is the boiler efficiency on the basis of net calorific value?

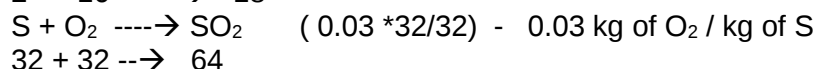
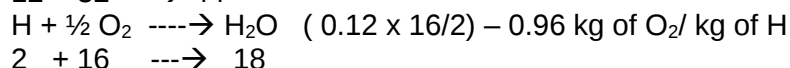
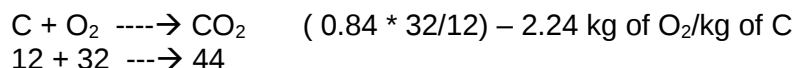
Ans:

$$\begin{aligned}\text{NCV} &= \text{GCV} - [9 \times (\% \text{age of Hydrogen in fuel}/100) + (\% \text{age of Moisture in fuel}/100) \times 584] \\ \text{NCV} &= 10500 - [9 \times (12/100) + (1.0/100) \times 584] \\ &= 9863 \text{ kCal/kg.}\end{aligned}$$

$$\text{Boiler efficiency on NCV} = 85 \times 10500 / 9863 = 90.48\%$$

- S-5 For combustion of 500 lit/hr of furnace oil, estimate combustion air quantity per hour with 20% excess air. Specific gravity of furnace oil 0.95. (Fuel analysis: C - 84%, H -12%, S - 3% O - 1%)

Ans:



$$\begin{aligned}\text{Total O}_2 \text{ required} &= (2.24 + 0.96 + 0.03 - 0.01) = 3.22 \text{ kg of O}_2/\text{kg fuel} \\ &= (3.22 / 0.23) = 14 \text{ kg of air}\end{aligned}$$

Excess air = 20%

$$\text{Air supplied} = (1 + 0.2) \times 14 = 16.8 \text{ kg of air / kg of oil}$$

$$\text{Quantity of F.oil} = 500 \text{ lit/hr} \times 0.95 = 475 \text{ kg/hr}$$

$$\text{Total quantity of air required} = 475 \times 16.8 = 7980 \text{ kgs of air /hr}$$

- S-6 What is meant by critical point of steam and give two advantages of Super Critical boilers?

Ans:

The critical point is the highest temperature at which liquid can exist. Any compression at constant temperature above the critical point will not produce a phase change. Compression at constant temperature below the critical point however, will result in liquefaction of the vapour as it passes from the superheated region into the wet steam region. The critical point occurs at 374.15°C and 221.2 bar (a) for steam and at this point the latent heat of steam is zero.

Advantages of super critical boiler

- Higher Heat Transfer Rate
- More Flexible in accepting load variations
- Greater ease of operation

- High thermal efficiency of 40-42%
- The absence of two phase mixture minimize the problem of erosion and corrosion
- Steadier Pressure level

S-7 What is meant by trigeneration? Explain how trigeneration can be applied in a hotel using DG set continuously for power generation.

Ans:

Trigeneration refers to simultaneous generation of steam (heat), power and refrigeration through integrated systems. Industries requiring electricity, steam and cooling such as food processing and cold storages find the concepts of tri-generation very attractive.

In a Hotel, power can be generated from DG sets and with the waste heat, steam can be generated. This steam can be used for both Vapour absorption system for generating chiller water for AC applications and also for generating hot water .

S-8 Calculate the induction melting furnace efficiency from the following melt cycle data

Mild steel (MS) scrap charged	: 1500 kg
Specific heat of MS	: 0.682 kJ/kg °C
Latent heat of MS	: 272 kJ/kg
MS melting temperature	: 1650 °C
Inlet MS charge temperature	: 40 °C
Electricity consumed during cycle	: 1020 kWh

Ans:

Theoretical energy required for melting = $1500 (0.682 \times (1650 - 40) + 272) / 3600$ kWh
= 570.8 kWh

Actual input	= 1020 kWh
Furnace efficiency	= $570.8 \times 100 / 1020$
	= 56%

----- 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

Paper 2 –Set A Solutions

- L-1 A steam pipeline of 100 mm outer diameter is not insulated for 100 meters and supplying steam at 10 kg/cm². Find out the annual fuel savings if the line is properly insulated with 65 mm insulating material. Assume 7000 hours/year of operation.

Given:

Boiler efficiency	- 85%
Fuel Oil cost	- Rs.32,000/tonne
Calorific Value of fuel oil	- 10,300 kCal/kg
Surface temperature without insulation	- 180 °C
Surface temperature after insulation	- 75 °C
Ambient temperature	- 30 °C

Ans:

$$\begin{aligned}\text{Existing heat loss} &= \{10 + (T_s - T_a)/20\} \times (T_s - T_a) \\ &= 2625 \text{ kCal/hr per Square meter}\end{aligned}$$

$$\begin{aligned}\text{Heat loss after insulation} &= (10 + (75 - 30)/20) \times (75 - 30) \\ &= 551.25 \text{ kCal/hr - Sq. m}\end{aligned}$$

$$\begin{aligned}\text{Surface Area Existing} &= 3.14 D L \\ &= 3.14 \times 0.1 \times 100 = 31.4 \text{ Square meter}\end{aligned}$$

$$\text{Surface Area after insulation} = 3.14 \times 0.23 \times 100 = 72.2 \text{ Square meter}$$

$$\text{Heat loss existing} = 2625 \times 31.4 = 82,425 \text{ kCal/hr}$$

$$\text{Heat loss after insulation} = 551.25 \times 72.2 = 39,811 \text{ kCal/hr}$$

Annual savings	$(82,425 - 39,811) \times 7,000 \times 32,000$
	$10,300 \times 1000 \times 0.85$

$$= \text{Rs. 10.9 Lakhs}$$

- L-2 Briefly explain the working principle of **any two** of the following

- Condenser in a steam power plant
- Distillation tower in a refinery
- Multi-effect Evaporator

Ans:

- Condenser: In steam applications, condenser is associated with condensing steam turbines and with ejector systems. In steam turbine applications, condenser remove significant amount of latent heat from the exhaust steam allowing it to be recovered as condensate. In steam ejector applications, condenser increases the effectiveness of the ejector by condensing both the motive steam and condensable pulled from the process.

Condensers are supplied with cooling water that circulates through condenser tubes providing a cool surface area that causes steam condensation.

- b) Distillation tower : The petroleum refining and chemical manufacturing industries use large amount of steam to facilitate the separation of crude oil or chemical feed stocks into various components. This separation process relies on difference in the boiling points of these various components. Steam is injected into bottom of these towers to reduce the partial pressure of the hydrocarbons, which facilitates their separation and to reduce coke formation on tray tower surfaces.
- c) Multi-effect Evaporator : In multi-effect Evaporator, the latent heat of the vapour product of an effect is used to heat the following effect. Effects are thus numbered beginning with the one heated by steam. It will have the highest pressure. Vapour from effect I will be used to heat effect II, which consequently will operate at low pressure. This continues throughout the train, pressure drops through the sequence so that the hot vapour will travel from one effect to the next.

L-3 a) Briefly explain the significance of LMTD in a heat exchanger

- b) In a double pipe heat exchanger hot fluid is entering at 330 °C and leaving at 170 °C. Cold fluid enters at 30 °C and leaves at 120 °C. Calculate LMTD, if the flow is counter current.

Ans:

- (a) The driving force for any heat transfer process is the temperature difference between two fluids. In the heat transfer process, the temperature of the two fluids keep changing as they pass through the heat exchange, for which some types of average temperature is needed. The average temperature difference through the heat exchange is described by the log mean temperature difference (LMTD). The larger the temperature difference, the smaller the required heat exchange area and vice versa.

- (b) LMTD Counter current flow

$$\begin{aligned}\Delta t_1 &= 330 - 120 = 210\text{ }^{\circ}\text{C} \\ \Delta t_2 &= 170 - 30 = 140\text{ }^{\circ}\text{C} \\ \text{LMTD} &= \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}} \\ &= \frac{210 - 140}{\ln \frac{210}{140}} = 172.64\text{ }^{\circ}\text{C}\end{aligned}$$

- L-4 In a chlor alkali plant, 120 TPD caustic solution at 33% concentration is dried to 50% concentration. The existing single effect evaporator, where steam input to moisture removal ratio is 1.0 kg/kg is proposed to be replaced by a triple effect evaporator where the ratio of steam input to moisture removal is 0.4 kg/kg. Calculate annual fuel cost

savings for 300 days operation at an evaporation ratio of 12 in the oil fired boiler and cost of FO Rs. 30,000/Tonne.

Ans.:

Dry caustic	= 120 TPD x 0.33 = 40 TPD
Inlet moisture / day	= (120 – 40) = 80 TPD
Outlet moisture / day	= 40 / 0.5 = 80
Moisture removed/ day	= 80 TPD – 40.0 = 40 TPD
Initial steam consumption at 1 kg/kg	= 40 TPD
Steam consumption with triple effect evaporator at 0.4 kg/kg	= 40 x 0.4 = 16 TPD
Steam savings per day	= 40 - 16 = 24 TPD
FO savings / day at evaporation ratio of 12	= 2 TPD
Rupee savings per day at Rs. 30,000/MT	= Rs. 60,000
Annual monetary savings at 300 days working	= Rs. 180 Lakhs

L-5 Write short notes on **any two** of the following

- a) Wet preservation method for boilers
- b) Reverse osmosis
- c) Reciprocating engine co-generation system

Ans:

- a) **Wet preservation method for boilers:** In the wet method the boiler is filled to the normal level with water at a pH of 10.5 to 11. Hydrazine to the extent of 200 ppm is to be dosed with the water. The unit is to be steamed in service to ensure uniform concentration of boiler water throughout the unit and to eliminate dissolved oxygen from water. Sodium sulphite (Na_2SO_3), which acts as a de-oxygenator, can also be used as an alternative to hydrazine and the sulphite concentration has to be maintained at 300-400 ppm.

Analysis of boiler water should be carried out frequently. If the hydrazine concentration in water happens to drop below 50 ppm, the water in the drum should be lowered to the normal operating level and an appropriate quantity of chemicals should be dosed to bring back 200 the concentration of hydrazine or sodium sulphite. The boiler should be steamed to circulate chemicals to uniform concentration.

- b) **Reverse osmosis:** When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration, which is called osmosis. If the solution of high concentration is pressurized, the process is reversed and the water from

the solution of high concentration flows to the weaker solution. This is known as reverse osmosis.

- c) **Reciprocating engine co-generation system:** Also known as internal combustion (I. C.) engines, these cogeneration systems have high power generation efficiencies in comparison with other prime movers. There are two sources of heat for recovery: exhaust gas at high temperature and engine jacket cooling water system at low temperature. As heat recovery can be quite efficient for smaller systems, these systems are more popular with smaller energy consuming facilities, particularly those having a greater need for electricity than thermal energy and where the quality of heat required is not high, e.g. low pressure steam or hot water.

L-6 a) Write short notes on hot blast cupola

- b) In an industry an electrical oven consuming 1000 kWh/batch is proposed for replacement by a fuel fired oven. Calculate the simple payback period for the following data:

Number of batches / year	= 4000
Efficiency of electric oven	= 80%
Efficiency of FO fired oven	= 55%
Cost of FO	= Rs. 30,000/Tonne
GCV of FO	= 10200 kCal/kg
Electricity cost	= Rs. 5.0 /kWh
Investment for FO fired oven	= Rs. 125 Lakhs

Ans:

- a) **Hot Blast Cupola**

The temperature of exhaust gas of a cupola is as high as 800 °C, making it possible to preheat blast air up to as high as 400 °C by heat exchange. In addition, both the sensible and latent heat of exhaust gas can be recycled for preheating blast air by combustion of CO gas included in exhaust gas. When blast air is preheated to 300 °C or higher, the sensible heat of blast air is added to heat input, activating combustion of coke, leading to the rise in combustion temperature

- b)
- | | |
|------------------------------------|---------------------------|
| The useful heat per batch required | = 1000 x 860 x 0.8 |
| | = 688000 kCal/batch |
| FO input per batch | = 688000 / (0.55 x 10200) |
| | = 122.6 kg |
| Electricity cost per batch | = Rs. 5 x 1000 |
| | = Rs. 5000 |
| FO cost per batch | = 122.6 x Rs. 30 |
| | = Rs. 3678 |

Paper 2 –Set A Solutions

Cost savings per batch	= Rs. 1322
Annual cost savings at 4000 batches	= Rs. 52,88,000
Initial investment	= Rs. 125 lakhs
Simple payback period	= 2.23 years

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