13th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS - September 2012

PAPER – 2:	**Energy Efficiency in Thermal Utilities**		
Date: 15.9.2012	Timings:14:00-17:00Hrs	Duration:3 Hrs	Max.Marks:150

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

(i) Answer all **50** questions
(ii) Each question carries **one** mark

1.	Steam mains are run with a slope primarily to a) avoid water hammer b) increase the velocity of steam c) avoid condensation of steam d) reduce radiation and convection losses
2.	Which of the following is not true of condensate recovery? a) reduces water charges b) reduces fuel costs c) increases boiler output d) increases boiler blow down
3.	If 10% air is entrained in a steam system at 3 kg/cm^2 g then the saturation temperature of steam will be a) less than the saturation temperature at 3 kg/cm^2 g b) more than the saturation temperature at 3 kg/cm^2 g c) equal to the saturation temperature at 3 kg/cm^2 g d) equal to the saturation temperature at 3.3 kg/cm^2 g
4.	The mineral matter in coal after combustion mostly becomes a) carbon dioxide b) carbon monoxide c) nitrous oxide d) ash
5.	Conditioning of coal with water in certain boilers is done to a) increase unburnt losses b) increase GCV c) minimize losses of fine coal particles d) increase convection heat transfer
6.	Which of the following is false? a) LPG vapour is twice as light as air b) LPG is a mixture of propane and butane c) LPG is a gas at normal atmospheric pressure d) LPG is required to be odorized
7.	Of the following fuels, which will have the highest carbon content? a) furnace oil b) coal c) natural gas d) paddy husk

8.	100 kg of a fuel contains 2% sulphur. For complete combustion of sulphur it will require _________kg of oxygen a) 2 b) 4 c) 50 d) 200
9.	In the direct method of efficiency evaluation of boilers which of the following is not required? a) enthalpy of steam b) calorific value of fuel c) O_2 in flue gas d) mass flow rate of steam
10.	Select the incorrect statement with respect to steam a) evaporation is a constant temperature process b) higher the pressure higher is the steam saturation temperature c) higher the pressure higher is the latent heat d) latent heat at critical point is zero
11.	The amount of flash steam generated from the condensate mainly depends on _____ a) sensible heat of high pressure condensate b) sensible heat of flash steam c) latent heat of flash steam d) all of the above
12.	Tuyeres is a terminology associated with a) induction furnace b) pusher type furnace c) arc furnace d) cupola
13.	In determining the economic thickness of steam pipe insulation which of the following is not required? a) cost of fuel b) boiler efficiency c) steam pressure d) heat content of fuel
14.	The softening temperature of a refractory is indicated by a) Pyrometric cone equivalent (PCE) b) refractoriness under load (RUL) c) creep d) cold crushing strength
15.	Which of the following is not a property of ceramic fibre ? a) low thermal conductivity b) light weight c) high heat capacity d) thermal shock resistant
16.	Low combustion temperature in FBC boilers results in the reduced formation of a) NOx b) SOx c) CO d) CO_2
17.	An axial compressor is used in conjunction with which of the following a) gas turbine b) back pressure steam turbine c) condensing steam turbine d) all of the above
18.	Power is to be generated from a cement kiln exhaust gas. The applicable type of cogeneration is called a) topping cycle b) trigeneration c) bottoming cycle d) none of the above
19.	The effectiveness of a heat exchanger does not depend on

	a) specific heat of hot fluid b) specific heat of cold fluid c) inlet temperature of hot fluid d) LMTD
20.	An element in fuel oil responsible for corrosion in exhaust system of a boiler is a) carbon b) hydrogen c) sulphur d) chlorine
21.	The presence of calcium and magnesium bicarbonates in feedwater to a boiler would form: a) acidic solution b) alkaline solution c) neutral solution d) none of the above
22.	Turn down ratio of a burner is the ratio of a) maximum to minimum fuel input without affecting optimum excess air levels b) minimum to maximum fuel input without affecting optimum excess air levels c) maximum to average fuel input d) average to minimum fuel input
23.	Comparatively, lowest excess air is required in a a) coal burner b) low pressure oil burner c) high pressure gas burner d) high pressure oil burner
24.	The velocity of steam in steam pipe is directly proportional to a) number of bends in pipe b) specific volume of steam c) length of pipe d) diameter of the pipe
25.	The emissivity of ceramic coatings used in furnace a) decreases with increase in furnace temperature b) Increases with increase in furnace temperature c) remains constant d) decreases with increase in furnace pressure
26.	Scale losses in reheating furnaces will a) increase with excess air b) decrease with excess air c) have no relation with excess air d) increase with CO in combustion gases
27.	Instrument used for measuring billet temperature in a reheating furnace is ___. a) thermograph b) infrared pyrometer c) Pt/Pt-Rh thermocouple with indicator d) chrome alumel thermocouple with indicator
28.	Glass mineral wool can be applied for temperature range application upto a) 950 ^{o}C b) 500 ^{o}C c) 1200 ^{o}C d) 750 ^{o}C
29.	Heat transfer in a reheating furnace is achieved by a) Conduction b) Convection c) Radiation d) All of the above
30.	The storage heat losses in a batch type furnace can be best reduced by a) insulating brick b) ceramic fibre c) cold face insulation d) fire brick
31.	The cogeneration system which has high overall system efficiency is a) back pressure steam turbine b) combined cycle

	c) extraction condensing steam turbine d) reciprocating engine
32.	The Brayton cycle is a characteristic of a) steam turbine b) petrol engine c) gas turbine d) none of the above
33.	Recuperator as a waste heat recovery system is used mainly in a a) boiler b) reheating furnace c) compressor d) gas turbine
34.	The device used for recovering waste heat from the textile drier exhaust a) heat wheel b) recuperator c) economizer d) regenerator
35.	Density of liquid fuels are measured at a reference temperature of a) 0°C b) 15°C c) 25°C d) 30°C
36.	Which of the following contributes to erosive effect on burner tips during combustion? a) ash content b) water content c) sulphur content d) volatile matter
37.	In the context of cogeneration turbine, the thermodynamic process taking place is a) expansion b) condensation c) contraction d) both (a) & (c)
38.	Reduction of steam pressure will increase a) sensible heat b) enthalpy of steam c) saturation temperature d) specific volume
39.	Ten meter lift of condensate in a distribution pipe work will result in a) 0.1 bar back pressure b) 1 bar back pressure c) 10 bar back pressure d) none of the above
40.	_____________ is predominantly used as a medium for soot blowing in boilers . a) compressed air b) steam c) high pressure water d) all of the above
41.	The recommended TDS level for package fire tube boilers is a) 10,000 ppm b) 5,000 ppm c) 2,000 ppm d) 3,000 ppm
42.	Ideal furnace for melting & alloying is a) induction furnace b) cupola furnace c) rotary hearth d) recirculating bogie furnace
43.	Commonly used flux medium in a cupola furnace a) calcium carbide b) fluorspar c) calcium carbonate d) sodium carbonate

44.	Dolomite is a ________ type of refractory a) acidic b) basic c) neutral d) none of the above
45.	The unit of specific gravity in SI system is a) kg/ m^3 b) m^3/kg c) gm/cc d) none of the above
46.	Insulation used for temperatures more than 350°C is a) polyurethane b) polystyrene c) calcium silicate d) wood
47.	Time dependent property that determines the deformation of a refractory is a) creep b) refractoriness under load c) porosity d) crushing strength
48.	Capillary wick is a part of a) heat pump b) heat wheel c) heat pipe d) heat recovery steam generator
49.	The working fluid for thermo compressor is a) low pressure steam b) high pressure steam c) compressed air d) waste heat from chimney
50.	Fly ash in a FBC boiler is in the range of a) 20% b) 30% c) 40% d) none of the above

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

(i) Answer all **8** questions
(ii) Each question carries 5 marks

S-1 In a paper industry, 35,000 kg/hr of soda liquor with specific heat of 0.38 kCal/kg°C is heated using saturated steam at 8 bar in a heat exchanger from 65°C to 115°C. Calculate the LMTD of the exchanger & the amount of steam required for heating using the following data:

Steam Pressure (bar)	Steam Temperature °C	Enthalpy kcal/kg		
		Water	Evaporation	Steam
8.0	170	170	490	660

Ans	a) Heat gain by soda liquor = 35000 x 0.38 x (115-65) = 665000 Kcal/hr Heat lost by saturated steam = 665000 Kcal/hr Steam required for heating = 665000 / 490 = 1357 Kg/hr Amount of steam required for heating is 1.36 Ton/hr b)LMTD calculation = $\frac{(170-115)-(170-65)}{\ln \frac{(170-115)}{(170-65)}}$ = (55-105)/ln(55/105) = 77.3°C
S-2	A process requires 5.5 tonnes/hr of dry saturated steam at 7 kg/cm^{2}g having specific volume of 0.28 m^3/kg. For the flow velocity not to exceed 25 m/s, determine the pipe diameter.
Ans	Volumetric flow rate = 5500 x 0.28 = 1540 m^3/hr = 1540/3600 = 0.43 m^3/s Cross sectional area = volumetic flow rate / velocity = 0.43 / 25 3.14 x D^2/4 = 0.017 D^2 = 0.0217 Diameter, D = 0.149 m (or) 150 mm
S-3	a) 230 kg/hr of hot condensate from a heat exchanger is coming out at 6 bar(g) with a sensible heat of 166 kCal/kg. Using a flash vessel, the condensate is flashed to 1 bar(g) with a sensible heat of 120 kCal/kg and latent heat of 526 kCal/kg. Find out the flash steam generation in kg/hr. b) The flash steam produced above is used to heat water from 30^{o}C to 80^{o}C by direct injection. Calculate the quantity of hot water in that can be obtained per hour.
Ans	a) Flash steam available % =(S1 - S2) / L2 S1 = is the sensible heat of higher pressure steam S2 = is the sensible heat of the steam at lower pressure L2 = is the latent heat of flash steam (at lower pressure) Flash Steam generated = $\frac{(166 - 120) \times 230}{526}$ = 20.11 Kg/hr. b) Quantity of hot water generated

	m x cp x (80-30) = 20.11 x (120+526) m = 260 kg/hr
S-4	The evaporation ratio of a coal fired boiler is 4.50. A quantity of 600 kCal/kg of heat is added to the feed water in the boiler to produce the steam. a) If the GCV of coal is 3800 kCal/kg, find out the efficiency. b) Find out the total enthalpy of the steam as per the details of the data given below Saturation temperature = 143^{o}C Sensible heat = 143.7 kCal/kg Latent heat = 509.96 kCal/kg Specific volume = 0.47 m^3/kg Dryness fraction of steam = 96%
Ans	a) Boiler efficiency (%) = $\frac{\text{Evaporation ratio x enthalpy added x 100}}{\text{GCV of coal}}$ Boiler efficiency = 4.5 x 600/3800 = 71 % b) Total enthalpy of steam = 143.7 + (0.96 x 509.96) = 633.26 kCal/kg
S-5	a. 'Steam should be used in the process at the lowest acceptable pressure ' . Explain the significance of the terms 'lowest' and 'acceptable' b. Explain briefly about 'turbine heat rate'. How is it related to turbine efficiency ?
Ans	**a.** 'lowest' : Lower the pressure higher is the latent heat which is primarily used in the process. Hence the lowest pressure would be desirable. 'acceptable': However the lower the steam pressure lower will be the steam temperature. Since the temperature is the driving force for heat transfer, rate of heat transfer reduces and increases process time. Therefore there is a limit to the reduction in steam pressure. **b.** Heat rate is the heat input to turbine, needed to produce 1 kWh of electricity Turbine efficiency is the ratio useful heat and power output, to the heat input to the turbine in Kcal or KJ, expressed as a percentage. Performance of steam turbine is also expressed as heat rate, which is the quantity of heat in kCal or KJ required to generate 1 kWh of electrical power output. Turbine heat rate is expressed in kJ/kWh. The inverse relation between heat rate and efficiency is applicable only to a power plant, since all the input energy is deployed for power generation alone.

S-6	Write short notes on factors affecting wall losses in batch type reheating furnaces?
Ans	a) Emissivity of walls : Emissivity of fire brick refractory should be high Emissivity of most of the refractory bricks decreases with increase in temperature. High emissivity coatings whose emissivity increases with temperature can be used to increase emissivity and decrease wall losses. b) Conductivity of refractories: The refractory and insulating bricks should have low thermal conductivity. Chosing low thermal conductivity bricks will reduce wall losses. Conductivity raises with rise in temperature. Batch type furnaces can use ceramic fibre to reduce storage losses. c) Wall thickness of batch furnaces: Heat losses can be reduced by increasing the **wall thickness**, or through the application of insulating bricks. Outside wall temperature and heat losses for a composite wall of a certain thickness of firebrick and insulation brick are much lower due to lesser conductivity of may be worked out to reduce the heat storage.
S-7	Explain any two proven methods of testing steam traps**?**
ANS	There are two proven methods of testing of steam traps: - Sound method and Temperature method. **1.Sound Method :** Mechanisms within steam traps and the flow of steam and condensate through steam traps generate sonic (audible to the human ear) and supersonic sounds. Proper listening equipment, coupled with the knowledge of normal and abnormal sounds, can yield reliable assessments of steam trap working condition. Listening devices range from a screwdriver or simple mechanic's stethoscope that allow listening to sonic sounds. **2.Temperature Method:** Saturated steam and condensate exist at the same temperature. So it's not possible to distinguish between the two based on temperature. Still, temperature measurement provides important information for evaluation purposes. A cold trap (i.e., one that is significantly cooler than the expected saturated steam temperature) indicates that the trap is flooded with condensate, assuming the trap is in service. On the other hand, the temperature downstream of the trap will be nearly constant if significant steam is getting past the trap. At the low-end, spitting on the trap and watching the sizzle provides a general indication of temperature.

	Finally, non-contact (i.e., infrared) temperature measuring devices provide the precision of thermometers and thermocouples without requiring physical contact. Non-contact temperature measurement makes it easier to evaluate traps that are relatively difficult or dangerous to access closely.
S-8	A vessel has to be cooled from 90°C to 55°C. The mass of the vessel is 2 tonnes. The specific heat of vessel material is 0.18 kCal/kg °C. The vessel is cooled with water which is available at 28°C. The maximum allowed increase in water temperature is 5°C. Calculate the quantity of water required for vessel cooling.
Ans	Mass of vessel (m) = 2000 kg Specific heat (Cp) = 0.18 kCal/kg °C Initial vessel temperature (T1) = 90°C Desired vessel temperature (T2) = 55°C Total heat that has to be removed from the vessel = m x Cp x (T1 - T2) = 2000 x 0.18 x (90-55) = 12600 kCal Quantity of water required = M kg Specific heat of water = 1 kCal/kg °C Inlet cooling water temperature (T3) = 28°C Maximum cooling water outlet temperature (T4) = 33°C Heat removed by water, 12600 = M x 1 x (33 - 28) Quantity of water required , M = 12600/5 = 2520 kg

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

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

(i) Answer all **6** questions
(ii) Each question carries **10** marks

L-1	Paddy husk is being used as a fuel in a water tube boiler. The ultimate analysis of fuel is given below. Calculate the theoretical quantity of air required for complete

combustion and also compute the quantity of CO_2, H_2O and SO_2 generated per 100 kg of fuel. The ultimate analysis of paddy husk is given below.

Ultimate analysis of paddy husk	%
Moisture	10.8
Mineral Matter	16.7
Carbon	34.0
Hydrogen	5.0
Nitrogen	0.9
Sulphur	0.1
Oxygen	32.5
GCV (kCal/kg)	3570

ANS

Considering a sample of 100 kg of paddy husk. The chemical reactions are:

Oxygen required for complete combustion of carbon:

C + O2 à CO2
(34.0) C + (34 x 2.67) O2 à **124.78** CO2
90.78

Oxygen required for complete combustion of hydrogen:

H2 + O2 à H2O

(5) H2 + (5 x 8) O2 à **45** H2O
40

Oxygen required for complete combustion of sulphur:

S + O_2 à SO_2

(0.1) S + (0.1 x 1) O_2 à **0.2** SO_2
0.1

Total Oxygen required = 90.78 + 40 + 0.1 = 130.88

Oxygen already present in 100 kg fuel (given) = 32.5 kg
Additional Oxygen Required = 130.88 -32.5 = 98.38
Therefore quantity of dry air reqd. = (98.38) / 0.23 = 427 kg

CO_2 generated per 100 kg of fuel = 124.78 kg
H_2O generated per 100 kg of fuel = 45 kg

SO_2 generated per 100 kg of fuel = 0.2 kg

L-2

In a crude distillation unit of a refinery, furnace is operated to heat 500 m^3/hr of crude oil from 255°C to 360°C by firing 3.4 tons/hr of fuel oil having GCV of 9850 kcal/kg. As an energy conservation measure, the management has installed an air preheater

	(APH) to reduce the flue gas heat loss. The APH is designed to pre-heat 57 tonnes/hr of combustion air to 195°C. Calculate the efficiency of the furnace before & after the installation of APH. Consider the following data: • Specific heat of crude oil = 0.6 kcal/kg°C • Specific heat of air = 0.24 kcal/kg°C • Specific gravity of Crude oil = 0.85 • Ambient temperature = 28°C.
ANS	<u>Before the installation of APH</u> Heat gain by the crude = 500 x 1000 x 0.85 x 0.6 x (360-255) = 26775000 Kcal/hr Heat input to the furnace = 3.4 x1000x 9850 = 33490000 kcal/hr Efficiency of the furnace = 26775000 / 33490000 = 80 % <u>After the installation of APH</u> Heat gain by the crude = 500 x 1000 x 0.85 x 0.6 x (360-255) = 26775000 Kcal/hr Heat gain by Air-preheater = 57 x 1000 x 0.24 x (195-28) = 2284560 Kcal/hr Heat reduction in input to the furnace = Heat gain by Air-preheater New Heat input to the furnace= 33490000 – 2284560 = 31,205,440 Efficiency of furnace after installation of APH = 26775000 / 31,205,440 = 85.8 %
L3	The management of a foundry is considering retrofitting the existing heat treatment furnace with hot face insulation of 75 mm ceramic fibre. (Note: Hot face insulation is known as veneering: ie over the existing refractory lining, ceramic fibre modules are applied to reduce the heat loss during operation and heat storage loss in refractory structure). <u>Furnace Operating data</u>**:** Heat Treatment furnace : (Bogey Type) Batch Operation Furnace Capacity : 5 Ton (per batch) Fuel type : Furnace Oil <u>Surface Area of</u> Side walls : (1.4 x 4.5) x 2 = 12.6 m^2 Back Wall : 0.95 x 1.4 = 1.33 m^2

	Roof : 0.95 x 4.5 = 4.3 m^2 Refractory Type : Fire Bricks <u>Wall Thickness</u> Side walls : 18 inches Arch : 13.5 inches Number of cold starts per month: 5 Nos. Number of batches per month: 15 Nos. Fuel Cost : Rs 48/ kg GCV of furnace oil : 10200 kCal/kg

Heat Storage (kCal /m^2) for batch operation and cold start from walls and roof area are given below.

	For batch operation		Cold Start	
	Existing(with only fire bricks)	75 mm Veneering+ fire bricks	Existing(with only fire bricks)	75 mm Veneering+ fire bricks
Wall	79480	45350	116697	23,964
Roof	74770	31,401	97,236	16,438

For batch operation furnace **is** heated from 300°C to 850°C
For cold start up furnace is heated from ambient 30 °C to 850°C

Calculate the following due to veneering

a) Total heat loss reduction per month from wall and roof during batch operation.
b) Total heat loss reduction per month from wall and roof during cold starts.

Ans

<u>Heat loss calculation for batch operation</u>

Heat reduction from Wall per m^2 = 79480-45350 =34130 Kcal

Heat reduction from total side wall & back wall = 34130 x13.93 =<u>475430.90</u> Kcal

Heat reduction from roof per m^2 = 74770- 31401 =43369 Kcal

Heat reduction from total roof area = 43369 x 4.3 = <u>186486.7</u> Kcal

Total heat reduction per batch from wall& roof = 475430. 90 + 186486.7
= 661917.60

Number of batches per month = 15 Nos

Total heat reduction per month from wall& roof = 661917.6 x15
= **9928764** Kcals/month

<u>Heat loss calculation for Cold Start</u>

Heat reduction from Wall per m^2 = 116697.5- 23,964.50 = 92733 Kcal

<table>
<tr><td></td><td>Heat reduction from total side wall & back wall = 92733 x13.93 = 1291770.69 Kcal
Heat reduction from roof per m^2 = 97,236 - 16,438.00 = 80798 Kcal
Heat reduction from total roof area = 80798 x 4.3 = 347431.4 Kcal
Total heat reduction per batch from wall& roof =1291770.69 + 347431.4
=1639202
Number of cold starts per month =5 Nos.
Total heat reduction per month from wall& roof = 8196010
Total heat reduction per month from operation and cold start =1,81,24,774kCal/month</td></tr>
<tr><td>L-4</td><td>a) Find out the efficiency of the furnace oil fired boiler by direct method in a agro product manufacturing plant with the data given below:

Type of boiler : Furnace oil fired
Quantity of steam (dry) generated : 5 Ton per hour (TPH)
Steam pressure / temp : 10 $kg/cm^2(g)$/ 180 ^oC
Quantity of oil consumed : 0.350 TPH
Feed water temperature : 75 ^oC
GCV of Furnace oil : 10400 kCal/kg
Enthalpy of saturated steam at 10 kg/cm^2 : 665 kCal/kg
Enthalpy of feed water : 75 kCal/kg

b) The above furnace oil fired boiler was converted to coconut shell firing. Determine the boiler efficiency by direct method after conversion.

GCV of coconut shell fuel : 4565 kCal/kg
Quantity of coconut shell consumed for the same steam demand and pressure. : 850 kg/hr

c) The cost of fuel and operating hour of boiler are given below.
• Operating hour/ year = 5000 hr
• Cost of furnace oil per ton = Rs 40000/ton
• Cost of coconut per ton = Rs 5000/ton
Find out the annual cost saving due to the fuel substitution fuel in the above boiler?</td></tr>
<tr><td>ANS</td><td>a)Boiler efficiency with furnace oil firing :

Boiler Efficiency (η) = 5000 x (665-75) x 100 / (350 x 10400)
Boiler efficiency = 81% (on GCV basis)

b)Boiler efficiency with coconut shell fuel firing :
Boiler Efficiency (η) = 5000 x (665-75) x 100/ (850 x 4565)
Boiler efficiency = 76% (on GCV basis)

c) Annual cost saving

Annual furnace oil cost = 5000Hr x 0.35 x Rs 40000</td></tr>
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= Rs.7.0 crore

Annual coconut shell Cost = 5000 hrs x 0.85x Rs.5000
= Rs. 2.125 crore

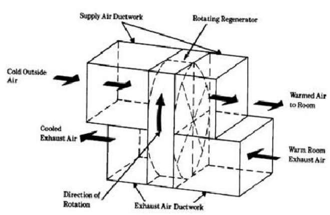
Annual cost saving = 7.0- 2.125= Rs 4.875 Crore

L5 Explain briefly <u>any two</u> of the following

a) Heat Wheel
b) Topping and bottoming cycles for cogeneration with examples
c) Economic thickness of insulation

Ans

a) Heat wheel



Widely used in low to medium temperature waste heat recovery systems.

A disk rotates between two side-by-side ducts: one a cold gas duct, the other a hot gas duct.

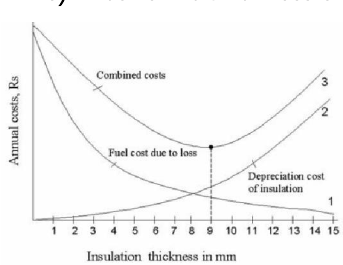
As the disk slowly rotates, sensible heat (moisture that contains latent heat) is transferred to the disk by the hot air and, as the disk rotates, from the disk to the cold air.

b) Topping and bottoming cycles for cogeneration with examples

In a topping cycle, the fuel supplied is used to first produce power and then thermal energy, which is the by-product of the cycle and is used to satisfy process heat or other thermal requirements ex. steam turbine, Diesel engine, Gas turbine etc.

In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator Power production from waste heat of cement plant, sponge iron plant etc

c) Economic thickness of insulation



As the insulation thickness increases heat loss cost reduces, At the same time insulation cost increases. Hence there is an optimum limit to thickness. The economic thickness of insulation is the thickness at which the combined cost is least.

<table>
<tr><td>L6</td><td>List five energy conservation measures in ANY TWO of the following:

a) Furnaces
b) Steam distribution systems
c) Boilers</td></tr>
<tr><td>Ans</td><td>a) Furnaces

1) Complete combustion with minimum excess air
2) Correct heat distribution
3) Operating at the desired temperature
4) Reducing heat losses from furnace openings
5) Maintaining correct amount of furnace draught
6) Optimum capacity utilization
7) Waste heat recovery from the flue gases
8) Minimum refractory losses
9) Use of Ceramic Coatings

b) Steam Distribution systems

1. Monitoring Steam Traps
2. Avoiding Steam Leakages
3. Providing Dry Steam for Process
4. Utilising Steam at the Lowest Acceptable Pressure for the Process
5. Minimising Heat Transfer Barriers
6. Proper Air Venting
7. Condensate Recovery
8. Insulation of Steam Pipelines and Hot Process Equipments
9. Flash Steam Recovery
10. Reducing the Work to be done by Steam

c) Boilers

1. Reduce Stack Temperature
2. Feed Water Preheating using Economiser
3. Combustion Air Preheating
4. Ensure complete Combustion
5. Control excess air
6. Radiation and Convection Heat Loss
7. Automatic Blowdown Control
8. Reduction of Boiler Steam Pressure
9. Variable Speed Control for Fans, Blowers and Pumps
10. Ensure boiler Loading for Efficiency
11. Boiler Replacement for efficiency</td></tr>
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