

Chapter 2.4: Furnaces

Part-I: Objective type Questions and Answers

1.	The hearth pressure in the heating zone of furnace should be: a) Slightly negative pressure b) <u>Slightly positive pressure</u> c) High negative pressure d) High positive pressure
2.	Which of the following furnaces have higher operating efficiency a) low temperature furnaces b) high temperature furnaces c) <u>continuous kiln</u> d) oven
3.	For optimum fuel consumption, the pressure at which furnaces operate should be ____. a) slightly negative b) <u>slightly positive</u> c) neutral d) any of the above
4.	In case of furnace performance, 'infiltration' is less harmful than 'exfiltration' when compared on energy efficiency aspects. - True or <u>false</u> ?
5.	The types of furnace in which preheating of air temperature will be maximum with respect to waste heat recovery system is ____. a) recuperative type b) <u>regenerative type</u> c) convective type d) none
6.	In large glass industries, the equipment connected with glass melting furnace for preheating the air is ____. a) recuperators b) <u>regenerators</u> c) shell & tube heat exchanger d) heat wheels
7.	Pick up the wrong statement: The thermal efficiency of the furnace increases by a) increasing the furnace loading b) <u>increasing the excess air flow rate</u> c) reducing the surface heat loss d) minimising the CO loss and unburnt losses
8.	If there is an opening on the furnace body, heat in the furnace escapes to the outside mainly as: a) <u>radiation heat</u> b) conduction heat c) convection heat d) none of the above
9.	In case of film burners, the excess air level maintained for optimum combustion is of the order of ____. a) 20-25% b) <u>5 to 10%</u> c) 15 to 20% d) none of the above
10.	The heat storage losses in ceramic fibre insulation in furnaces are maximum compared to other refractories – State True or <u>False</u> .

11.	Thermal efficiency of reheating furnace is of the order of a) 70 to 80% b) 65 to 70% c) <u>40 to 50%</u> d) 20 to 40%
12.	The efficiency of a reheating furnace, operating at 10 tonnes per hour consuming furnace oil of 230 kg/hour for reheating the material from 40 °C – 1100 °C (consider specific heat of material is 0.13 kCal / kg °C and calorific value of furnace oil is 10,000 kCal /kg) is ____. a) <u>60</u> b) 70 c) 80 d) 50
13.	The axis of the burner in a furnace should be kept: a) <u>slightly inclined towards the roof</u> b) more inclined towards roof c) slightly inclined towards the stock d) <u>parallel to stock</u>
14.	The equipment used in reheating furnaces to control the excess air is ____. a) <u>air/fuel ratio controller</u> b) air preheater c) fuel preheater d) flue gas cooler
15.	Thermal Conductivity of the refractories has an effect on heat losses from furnace walls. <u>True/False</u>
16.	The emissivity of ceramic coatings used in furnace: a) decreases with increase in temperature b) <u>Increases with increase in temperature</u> c) remains constant d) decreases with increase in furnace pressure
17.	Higher excess air in an oil fired furnace would result in: a) increased furnace temperature b) increased heating rate c) <u>reduced flame temperature</u> d) none of the above
18.	Instrument used for measuring billet temperature in a reheating furnace is ____. a) thermograph b) <u>infrared pyrometer</u> c) Pt/Pt-Rh thermocouple with indicator d) chrome alumnel thermocouple with indicator
19.	Normal operating temperature of rolling mill furnace is about a) 800 °C b) 900 °C c) 1000 °C (d) <u>1200 °C</u>
20.	In reheating furnace, scale losses will: a) <u>increase with excess air</u> b) decrease with the excess air c) will have no relation with excess air d) will increase with nitrogen in air

Part-II: Short type questions and answers

1.	Why the need for excess air arises in combustion systems? Excess air is always required for complete combustion. The method of air supply should be such that
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	there is intimate contact between oxygen and combustibles. This is achieved by creating turbulence in the combustion zone. Normally (in practice) the excess air should be about 10 to 15% more than the stoichiometric air requirement. However, there are burners which operate on 5 to 8% excess air also.
2.	What is the significance of optimizing furnace temperature? Furnaces must be operated at an optimum temperature. Too high a temperature will cause overheating of the stock leading to excess oxidation high thermal stresses on refractories and higher fuel consumption. High temperature operation also leads to reduced quality of the product or difficult in metal forming etc.
3.	What do you mean by turn down ratio of burner? The ratio of maximum heat input rate to minimum. It is the range within which the burner operates satisfactory.
4.	How do you determine excess air level in a furnace? Quantity of excess air can be determined by measuring the % O₂ or % CO₂ in the flue gas. With the measured volume of % CO₂, the excess air can be calculated by the following formula $\% \text{ excess air :- } \left(\frac{\text{Theoretical CO}_2 - \text{Actual CO}_2}{\text{Actual CO}_2} \right) \times 100$
5.	What is the effect of furnace draft? It is important to operate furnace at a slightly positive pressure. Negative pressure lead to air ex-filtration affecting air fuel ratio and furnace temperature thus increasing fuel consumption. Excessive positive pressure leads to infiltration resulting in leaking out of flames, overheating of furnace refractories, reduced brick life and other associated problems.
6.	List out different type of heat losses in furnaces. Different type of heat losses in furnaces. - Dry flue gas losses - Heat distribution losses - High temperature losses - Heat loss through openings - Draft losses - Radiation and convection losses(surface heat loss) - Heat carried by product carrying equipment (trolley, basket etc.)
7.	What does a combustion efficiency of furnace indicate? Combustion efficiency indicates the energy transferred from the fuel to the furnace.
8.	Differentiate between furnace and oven? Furnace is an equipment to melt metals for casting or heat materials for change of shape (rolling, forging etc.) or change of properties (heat treatment). When the furnace is operated below 370 °C temperature then it is called as oven, and when it operates above 370 °C temperature then the operating equipment is called furnace.

9.	Why heat treatment furnaces are used? Heat treatment furnaces are used for changing the properties of metals.
10.	Classify the furnaces based on material charging? Based on the mode of charging of material furnaces can be classified as (i) intermittent or batch type furnace or periodical furnace, and (ii) Continuous furnace
11.	List the three major parameters which are considered for classification of furnaces” The three major parameters which govern the furnace classification are – mode of heat transfer, mode of charging, mode of heat recovery
12.	Why LDO as fuel is preferred in some furnaces, even though cost of LDO is higher? LDO contains less sulphur compared to FO. LDO is used in furnaces, where presence of sulphur is undesirable. Due to this reason LDO is preferred over furnace oil (FO), even though cost of LDO is higher compared to FO.
13.	Name the applications where heat available in flue gases from the furnaces can be re-utilised at industry applications? The sensible heat in flue gas of a furnace can be generally salvaged by the following methods: i) Charge preheating ii) Preheating of combustion air iii) Utilizing waste heat for other process - to generate steam or hot water by waste heat boiler
14.	Which is the most attractive and economical measure for energy conservation in furnaces? The optimization of combustion air is the most attractive and economical measure for energy conservation. The impact of this measure is higher when the temperature of furnace is high.
15.	Mention the basic steps to be taken in a furnace to attain complete combustion with minimum amount of air? 1. control the air infiltration 2. maintain pressure of combustion air 3. good fuel quality 4. excess air monitoring.
16.	Name at least three additional care to be taken when burners are used for proper distribution of heat in a furnace. i) Flames should not touch solid object and should propagate clear of any solid object. ii) Flames should not impinge on refractories.

	iii) Flames should not intersect each other iv) The axis of the burner should be slightly upward angle (should not be parallel to hearth) and should not hit the roof.
17.	What is recuperator? Explain in brief? Recuperator is a heat exchanger installed to exchange heat between the waste gases and the air to be preheated. It usually consists of ducts and tubes, which carry air for combustion to be preheated.
18.	Name three devices generally used as waste heat recovery for furnaces? 1) Metallic recuperators (2) Ceramic recuperators and (3) Regenerators
19.	How do ceramic coatings help in reducing energy consumption in a furnace? Ceramic coatings in furnace chamber promote rapid and efficient transfer of heat, uniform heating and extended life of refractories. The emissivity of ceramic coated refractories increases with increase in temperature. Energy savings to an order of 8 to 10% can be achieved for high temperature applications.
20.	How do you evaluate the furnace performance by direct method? $\text{Thermal efficiency of the furnace} = \frac{\text{Heat in the stock}}{\text{Heat in the fuel consumed for heating the stock}}$ The quantity of heat to be imparted (Q) to the stock can be found from Q = m x C_p (t₁ – t₂), where Q = Quantity of heat of stock in Kcal m = Weight of the stock in Kg C_p = Mean specific heat of stock in kCal/kg°C t₁ = Final temperature of stock desired, °C t₂ = Initial temperature of the stock before it enters the furnace, °C

Part-III: Long type questions and answers

1.	What are the advantages of using minimum excess air for combustion for a furnace application? How it can be achieved? The optimization of combustion air is the most attractive and economical measure for energy conservation. The impact of this measure is higher when the temperature of furnace is high. Air ratio is the value that is given by dividing the actual air amount by the theoretical combustion air amount, and it represents the extent of excess of air. By providing minimum excess air for combustion, the exhaust losses can be reduced and hence reduced fuel consumption. To obtain complete combustion of fuel with the minimum amount of air, it is necessary to control air infiltration, maintain pressure of combustion air, fuel quality and excess air monitoring. Higher
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	excess air will reduce flame temperature, furnace temperature and heating rate. On the other hand, if the excess air is less, then unburnt components in flue gases will increase and would be carried away in the flue gases through stack. So correct excess air level keeping in a furnace saves fuel and also for some case reduces the scale losses.																						
2.	Explain the importance of furnace draft and its control? If negative pressures exist in the furnace, air infiltration is liable to occur through the cracks and openings thereby affecting air-fuel ratio control. Tests conducted on apparently airtight furnaces have shown air infiltration up to the extent of 40%. Neglecting furnace pressure could mean problems of cold metal and non-uniform metal temperatures, which could affect subsequent operations like forging and rolling and result in increased fuel consumption. For optimum fuel consumption, slight positive pressure should be maintained in the furnace. Ex-filtration is less serious than infiltration. Some of the associated problems with ex filtration are leaping out of flames, overheating of the furnace refractories leading to reduced brick life, increased furnace maintenance, burning out of ducts and equipment attached to the furnace, etc. In addition to the proper control on furnace pressure, it is important to keep the openings as small as possible and to seal them in order to prevent the release of high temperature gas and intrusion of outside air through openings such as the charging inlet, extracting outlet and peephole on furnace walls or the ceiling.																						
3.	In an industry one 30 kWh operating load, electrical furnace to be converted into furnace oil fired. Estimate the furnace oil (litre) requirement, considering the following: <table> <tr> <td>Calorific value of FO</td><td>: 9200 Kcal/kg</td></tr> <tr> <td>Density of FO (kg/litre at 15 °C)</td><td>: 0.9</td></tr> <tr> <td>Efficiency of electrical furnace</td><td>: 70%</td></tr> <tr> <td>Efficiency of FO fired furnace</td><td>: 55%</td></tr> </table> <table> <tr> <td>Operating electrical load</td><td>: 30 kWh</td></tr> <tr> <td>Efficiency of electrical furnace</td><td>: 70%</td></tr> <tr> <td>Useful heat</td><td>: $30 \times 860 \times 0.7 = 18060 \text{ kcal}$</td></tr> <tr> <td>For meeting useful heat required FO</td><td>: $18060 / 9200 = 1.96 \text{ kg}$</td></tr> <tr> <td>Efficiency of FO fired furnace</td><td>: 55%</td></tr> <tr> <td>Net FO required to meet useful heat</td><td>: $1.96 / 0.55 = 3.56 \text{ kg}$</td></tr> <tr> <td>Estimated furnace oil quantity</td><td>: $3.56 / 0.9 = 3.95 \text{ litres}$</td></tr> </table>	Calorific value of FO	: 9200 Kcal/kg	Density of FO (kg/litre at 15 °C)	: 0.9	Efficiency of electrical furnace	: 70%	Efficiency of FO fired furnace	: 55%	Operating electrical load	: 30 kWh	Efficiency of electrical furnace	: 70%	Useful heat	: $30 \times 860 \times 0.7 = 18060 \text{ kcal}$	For meeting useful heat required FO	: $18060 / 9200 = 1.96 \text{ kg}$	Efficiency of FO fired furnace	: 55%	Net FO required to meet useful heat	: $1.96 / 0.55 = 3.56 \text{ kg}$	Estimated furnace oil quantity	: $3.56 / 0.9 = 3.95 \text{ litres}$
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4.	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: <table> <tr> <td>Furnace capacity</td><td>: 180 kW</td></tr> <tr> <td>Loading capacity of furnace</td><td>: 10 Tonnes</td></tr> <tr> <td>Heat treatment cycle</td><td>: Heating up to 650 °C – 6 hours</td></tr> <tr> <td></td><td>: Soaking at 650 °C – 8 hours</td></tr> <tr> <td></td><td>: Cooling in furnace – 4 hours</td></tr> <tr> <td>Quantity of the stock to be treated</td><td>: 1000T/year</td></tr> </table> Evaluate the energy savings by optimum loading?	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	: 1000T/year										
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	Sp. Power consumption of stock: i) Load in furnace (1/3) : $10 \times 1/3 = 3.3 \text{ MT}$ Power consumption for 1/3rd load : 860 kWh/cycle Sp. Power consumption at 1/3rd load : $860/3.3 = 260.6 \text{ kWh/MT}$ ii) Load in the furnace (full) : 10 MT Power consumption at full load : 1600 kWh/cycle Sp. Power consumption at full load : $1600/10 = 160 \text{ kWh/MT}$ Reduction in power consumption at optimum load (full load) : $260.6 - 160 = 100.6 \text{ kWh/MT}$ Annual stock production : 1000 T By operating furnace with each batch of 10T (full load) Reduction in power consumption : 1000×100.6 : 100600 kWh/year
5.	Write few salient points about optimum capacity utilisation of furnaces. One of the most vital factors affecting efficiency of furnace is loading. There is a particular loading at which the furnace will operate at maximum thermal efficiency. The best method of loading is generally obtained by trial-noting the weight of material put in at each charge, the time it takes to reach temperature and the amount of fuel used. The loading of the charge on the furnace hearth should be arranged, so that: 1. It receives the maximum amount of radiation from the hot surfaces of the heating chambers and the flames produced. 2. The hot gases are efficiently circulated around the heat receiving surfaces Stock should not be placed in the following portion. i) In the direct path of the burners or where flame impingement is likely to occur. ii) In an area which is likely to cause a blockage or restriction of the flue system of the furnace. iii) Close to any door openings where cold spots are likely to develop. Optimum utilization of furnace can be planned at design stage. In case of batch type furnaces, careful planning of the loads is important. Furnace should be recharged as soon as possible to enable use of residual furnace heat.