

## Chapter 2.5: Insulation & Refractories

### Part-I: Objective type questions and answers

1.	A thermal insulator is a) good conductor of heat and has high thermal conductivity b) poor conductor of heat and has high thermal conductivity c) good conductor of heat and has low thermal conductivity d) <u>poor conductor of heat and has low thermal conductivity</u>										
2.	The insulation material suitable for low temperature application is a) Mineral fibre            b) Fibre glass            c) Silica            d) <u>polyurethane</u>										
3.	The insulation materials used for medium temperature application is a) Asbestos    b) Calcium silicate    c) Mineral fibre    d) <u>All of the above</u>										
4.	'Ceramic fibre insulation' is suitable up to temperature of a) 540 °C            b) 1050 °C            c) <u>1430 °C</u> d) 1850 °C										
5.	Match the following: <table style="width: 100%; border: none;"> <thead> <tr> <th style="text-align: left;">Insulating material</th> <th style="text-align: left;">Suitable temperature</th> </tr> </thead> <tbody> <tr> <td>a) Rockwool</td> <td>i) - 178 °C to 4 °C</td> </tr> <tr> <td>b) Fibre glass</td> <td>ii) -167 °C to 82 °C</td> </tr> <tr> <td>c) Polystyrene</td> <td>iii) Up to 820 °C</td> </tr> <tr> <td>d) Polyurethane</td> <td>iv) Up to 540 °C</td> </tr> </tbody> </table> a-iii); b-iv); c-ii); d-i)	Insulating material	Suitable temperature	a) Rockwool	i) - 178 °C to 4 °C	b) Fibre glass	ii) -167 °C to 82 °C	c) Polystyrene	iii) Up to 820 °C	d) Polyurethane	iv) Up to 540 °C
Insulating material	Suitable temperature										
a) Rockwool	i) - 178 °C to 4 °C										
b) Fibre glass	ii) -167 °C to 82 °C										
c) Polystyrene	iii) Up to 820 °C										
d) Polyurethane	iv) Up to 540 °C										
6.	Select the suitable cost effective insulation for steam pipelines with temperature of 540 °C. a) calcium silicate    b) <u>fibre glass</u> c) rock wool    d) Alumina										
7.	The unit for thermal coefficient of insulation and refractories is SI system is _____. a) K.cal/m-hr-°C    b) <u>K.cal/ m<sup>2</sup>-hr-°C</u> c) K.cal/m <sup>2</sup> -°C    d) K.cal/ m-°C										
8.	The coefficient of thermal expansion of refractory material should be _____. a) <u>low</u> b) High    c) Medium    d) very high										
9.	Magnesite, chrome-magnesite, dolomite are examples of ----- type of refractory a) acid    b) <u>basic</u> c) neutral    d) none of the above										

10.	Alumina is a _____ type of refractory. a) acid   b) basic   c) <u>Neutral</u> d) None of the above
11.	The heat conductivity of refractory material should be _____. a) <u>low</u> b) High   c) Medium   c) None
12.	The most common form of refractory material extensively used in the construction of small furnaces is----- a) silica bricks   b) <u>Fire brick</u> c) chrome magnesite   d) Calcium silicate blocks
13.	The thermal conductivity of a ideal refractory material should be _____. a) <u>low</u> b) high   c) medium   d) None of the above
14.	Mark the best choice of insulation material for electric heat treatment furnace among the following group. a) glass wool   b) calcium silicate   c) fire bricks   d) <u>ceramic fibre</u>
15.	The refractory which can resist most of the chemical attack and is unaffected by hydrocarbons, water and steam present in flue gas is ----- a) Alumina   b) <u>Ceramic Fibre</u> c) Fire Brick   d) Mineral Fibre
16.	High emissivity coatings are applied on: a) Outer surface of furnace   b) Refrigeration pipings c) <u>Inner surface of furnace</u> d) None of the above
17.	The content on which ceramic fibres will be produced in two temperature grades is _____. a) <u>Al<sub>2</sub>O<sub>3</sub></u> b) SiO <sub>2</sub> c) ZrO <sub>2</sub> d) All the above
18.	The component required to reduce shrinkage levels in alumino silicate fibre is _____. a) Al <sub>2</sub> O <sub>3</sub> b) <u>ZrO<sub>2</sub></u> c) SiO <sub>2</sub> d) All the above
19.	The effect of thermal conductivity on thermal resistance of an insulation is _____. a) Increases with increased thermal conductivity b) Decreases with decreased thermal conductivity c) <u>Decreases with increased thermal conductivity</u> d) Increases with decreases thermal conductivity
20.	The insulation which can be used for lining furnaces operating up to 1850°C is:

a) <u>Alumina</u> b) Zirconia    c) Dolomite    d) Calcium silicate
---

**Part-II: Short type questions and answers**

1.	<p>What is 'insulation'? List some of the common insulators used in industries</p> <p>A material which is poor conductor of heat and having a low thermal conductivity is termed as insulation. Some of the common insulators used in industries are; ceramic fibre, mineral wool, glass wool, calcium silicate</p>
2.	<p>What are the benefits of thermal insulation?</p> <p>Thermal insulation delivers the following benefits:</p> <ul style="list-style-type: none"> <li>- Reduces over-all energy consumption</li> <li>- Offers better process control by maintaining process temperature.</li> <li>- Prevents corrosion by keeping the exposed surface of a refrigerated system above dew point</li> <li>- Provides fire protection to equipment</li> <li>- Absorbs vibration</li> </ul>
3.	<p>What is the effect of thermal insulation on the equipment.</p> <p>Thermal insulation provided on equipments help to prevent either heat loss from the equipment or heat gain to the equipment.</p>
4.	<p>List any four commonly used industrial applications of insulation.</p> <p>The insulation is commonly used for the following industrial purposes.</p> <ul style="list-style-type: none"> <li>i) Air conditioning system</li> <li>ii) Refrigeration and food preserving stores</li> <li>iii) Boilers and steam pipes</li> <li>iv) Insulating bricks in all types of furnaces</li> </ul>
5.	<p>Classify different types of insulation as per the temperature range with an example</p> <p>The different types of insulation classified as per temperature range are</p> <ul style="list-style-type: none"> <li>• Low temperature insulation (up to 90°C) e.g. refrigerators, cold and hot water systems</li> <li>• Medium temperature insulation (90 -325°C) e.g. steam lines, flue ducts</li> <li>• High temperature insulation (325°C and above) e.g. super heated steam systems, furnaces</li> </ul>

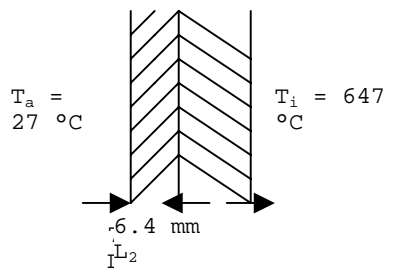
6.	<p>Name any two insulating material used for insulating steam pipelines</p> <p>Insulating materials used for steam pipelines are rock wool (mineral fibre) and glass fibre.</p>
7.	<p>List some of the applications of fibre glass and calcium silicate insulation materials?</p> <p>Fibre glass: It is mainly used to insulate industrial ovens, heat exchangers, driers, boilers and pipe work.</p> <p>Calcium silicate: Mainly used to insulate furnace walls, fire boxes, back up refractory, flue lining and boilers</p>
8.	<p>Describe how ceramic fibre is made. List some of the applications of it?</p> <p>Ceramic fibre is made from high purity alumina and silica grains, melted in an electric furnace and blasted by high velocity gases into light fluffy fibres. It is mainly used to insulate furnace and kiln back up refractory, fire boxes, glass feeder bowls, furnace repair, induction coil insulation, high temperature gaskets and wrapping material</p>
9.	<p>What is economic thickness of insulation?</p> <p>The effectiveness of insulation follows the law of decreasing returns. Hence, there is a definite economic limit to the amount of insulation, which is justified. An increased thickness is uneconomical and cannot be recovered through small heat savings. This limiting value is termed as economic thickness of insulation.</p>
10.	<p>What are the parameters required to evaluate economic thickness of insulation.</p> <p>For determination of economic thickness following parameters are required:</p> <ol style="list-style-type: none"> <li>i) Cost of fuel</li> <li>ii) Annual hours of operation</li> <li>iii) Heat content of fuel</li> <li>iv) Boiler efficiency</li> <li>v) Operating surface temperature</li> <li>vi) Pipe diameter / thickness of surface</li> <li>vii) Estimated cost of insulation</li> <li>viii) Average exposure ambient still air temperature</li> </ol>
11.	<p>Write the simple equation for heat loss calculation useful for up to 200 °C temperature.</p> <p>The surface heat loss can be computed with the help of a simple relation up to 200 °C surface temperature.</p> $S = [10 + (Ts-Ta) / 20] \times [Ts-Ta]$ <p>Where,</p> <p>S = Surface heat loss in kcal/hr m<sup>2</sup></p> <p>Ts = Hot surface temperature in °C</p>

	Ta = Ambient temperature in °C
12.	<p>Describe the term 'refractory material'.</p> <p>Any material, if it can withstand the action of abrasive or corrosive solids, liquids or gases at high temperatures are called 'refractory' material.</p>
13.	<p>In furnaces, apart from fuel savings, what are the other advantages by use of insulation? The advantages by use of insulation in furnaces, apart from fuel savings are:</p> <ol style="list-style-type: none"> <li>i) Offers better process control by maintaining process temperatures</li> <li>ii) Prevents corrosion by keeping higher flue gas temperatures above acid dew point.</li> <li>iii) Provides fire protection</li> <li>iv) Absorbs vibration</li> </ol>
14.	<p>What are the general requirements of a refractory material?</p> <p>The general requirements of a refractory material are</p> <ol style="list-style-type: none"> <li>i) Ability to withstand action of molten metal slag, glass, hot gases etc.</li> <li>ii) Ability to withstand load and abrasive forces</li> <li>iii) Low coefficient of thermal expansion</li> <li>iv) Should be able to conserve heat</li> <li>v) Should not contaminate the material with which it comes into contact</li> </ol>
15.	<p>What are the characteristics of acidic, basic and neutral type refractories?</p> <p>Acidic: it readily combines with base</p> <p>Basic: consists mainly of metallic oxides which resist the action of bases</p> <p>Neutral: does not combine neither with acids nor bases</p>
16.	<p>Describe in brief how selection of refractories is done? Describe with an example?</p> <p>The selection of refractories for any particular application is made with a view to achieve the best performance of the furnace, and depends on certain properties of the refractories. Firebrick is the most common form of refractory material used extensively in the construction of small furnaces. Other refractories which are used in furnace construction are high alumina brick, silica brick, magnesite brick, chromite brick, zirconia brick, monolithics etc.</p>
17.	<p>List important properties of ceramic fibre insulation?</p> <p>The properties are</p> <ul style="list-style-type: none"> <li>➤ Low thermal conductivity</li> <li>➤ Light Weight</li> <li>➤ Lower heat storage</li> <li>➤ Thermal shock resistant</li> </ul>

	<ul style="list-style-type: none"> <li>➤ Low installation cost</li> <li>➤ Simple maintenance</li> <li>➤ Ease of handling</li> </ul>
18.	<p>List the advantages of ceramic fibre insulation?</p> <p>The advantages are</p> <ul style="list-style-type: none"> <li>➤ Low Down time</li> <li>➤ Increased productivity</li> <li>➤ Low maintenance cost</li> <li>➤ Longer service life</li> <li>➤ Higher thermal efficiency</li> <li>➤ Faster response</li> </ul>
19.	<p>In the context of furnaces, what is high emissivity coating means?</p> <p>High emissivity coatings are applied in the interior surface of furnaces. The high emissivity coating allows the surface emissivity of materials to be increased, with resultant benefits in heat transfer efficiency and in the service life of heat transfer components.</p>
20.	<p>Describe 'emissivity' for a refractory material.</p> <p>Emissivity is the measure of material's ability to both absorb and radiate heat. Higher emissivity characteristic has benefit of heat transfer efficiency and service life of material. High emissivity coatings are applied at the interior surface of the furnace</p>

**Part-III: Long type questions and answers**

1.	<p>What do you mean by "Economic thickness of insulation"? Explain in details.</p> <p>This limiting value is termed as economic thickness of insulation. Each industry has different fuel cost and boiler efficiency. These values can be used for calculating economic thickness of insulation. This shows that thickness for a given set of circumstances results in the lowest overall cost of insulation and heat loss combined over a given period of time. The following figure shown below illustrates the principle of economic thickness of insulation.</p> <p>I: Cost of Insulation      H : Cost of Heat Loss</p> <p>I + H : Total Cost      M : Economic Thickness</p> <p>The determination of economic thickness requires the attention to the following factors.</p> <p>i. Annual hours of operation</p>
----	--

	<p>ii. Pipe diameter/thickness of surface</p> <p>iii. Estimated cost of insulation.</p> <p>Average exposure ambient still air temperature.</p>
<p>2.</p>	<p>A furnace wall is made of 75 mm thick fire clay brick and 6.4 mm thick mid steel plate. The inside surface of brick temperature is 647 °C and outside air temperature is 27 °C.</p> <p>Determine:</p> <p>i) The heat loss per m<sup>2</sup> area of the furnace wall.</p> <p>Consider      K1 (brick)      = 1.1 W/m-°C</p> <p>                  K2 (steel)      = 39 W/m-°C</p> <p>                  h<sub>0</sub> (outside heat transfer coefficient) = 68 W/m<sup>2</sup>-°C</p> <div style="text-align: center;">  <p>The diagram shows a cross-section of a furnace wall. It consists of two layers: an inner brick layer of thickness L1 and an outer steel plate of thickness L2. The inner surface of the brick is at temperature Ti = 647 °C. The outer surface of the steel plate is exposed to air at temperature Ta = 27 °C. The heat loss per unit area is denoted as Q.</p> </div> <p>Considering unit surface area</p> $R_{\text{brick}} = \frac{L1}{K1} = \frac{0.075}{1.1} = 0.0682$ $R_{\text{steel}} = \frac{L2}{K2} = \frac{0.0064}{39} = 1.64 \times 10^{-4}$ $R_{\text{Conv.}} = \frac{1}{h_0} = \frac{1}{68} = 0.0147$ $R_{\text{Total}} = R_{\text{brick}} + R_{\text{steel}} + R_{\text{cov}} = 0.083$ <p>ii) Q (heat loss per m<sup>2</sup> area) = <math>\frac{T_i - T_a}{R_{\text{Total}}}</math></p> $= \frac{647 - 27}{0.083} = 7460 \text{ W} / \text{m}^2$

3.	<p>Steam pipeline 100 mm diameter is not insulated for 100 metre length supplying steam at 10 kg/cm<sup>2</sup> to the equipment. Find out the fuel savings if it is properly insulated with 65 mm insulating material.</p> <p><i>Given:</i></p> <p>Boiler efficiency – 80%</p> <p>Fuel Oil cost - Rs.15000/tonne</p> <p>Surface temperature without insulation – 170°C</p> <p>Surface temperature after insulation – 65°C</p> <p>Ambient temperature – 25°C</p> <p><i>Existing Heat Loss</i></p> $S = [10 + (T_s - T_a) / 20] \times (T_s - T_a)$ <p><math>T_s = 170^\circ\text{C}</math></p> <p><math>T_a = 25^\circ\text{C}</math></p> $S = [10 + (170 - 25) / 20] \times (170 - 25) = 2500 \text{ Kcal/hr-m}^2$ <p><math>S_1 = S = \text{Existing heat loss (2500 Kcal/hr-m}^2)</math></p> <p><i>Modified System</i></p> <p>After insulating with 65 mm glass wool with aluminium cladding the hot face temperature will be 65°C</p> <p><math>T_s = 65^\circ\text{C}</math></p> <p><math>T_a = 25^\circ\text{C}</math></p> <p>Substituting these values</p> $S = [10 + (65 - 25) / 20] \times (65 - 25)$ $= 480 \text{ K.cal/hrM}^2$ <p><math>S_2 = S = \text{Existing heat loss (480 Kcal/hr-m}^2)</math></p> <p><b>Fuel Savings Calculation</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td>Pipe dimension</td> <td>=</td> <td>100 mm <math>\phi</math> &amp; 100 m length</td> </tr> <tr> <td>Surface area existing (A1)</td> <td>=</td> <td><math>3.14 \times 0.1 \times 100 = 31.4 \text{ m}^2</math></td> </tr> <tr> <td>Surface area after insulation (A2)</td> <td>=</td> <td><math>3.14 \times 0.23 \times 100 = 72.2 \text{ m}^2</math></td> </tr> <tr> <td>Total heat loss in existing system (S1 x A1)</td> <td>=</td> <td><math>2500 \times 31.4 = 78500 \text{ Kcal/hr}</math></td> </tr> <tr> <td>Total heat loss in Modified system (S2 x A2)</td> <td>=</td> <td><math>480 \times 72.2 = 34656 \text{ Kcal/hr}</math></td> </tr> <tr> <td>Reduction in heat loss</td> <td>=</td> <td><math>78500 - 34656 = 43844 \text{ Kcal/hr}</math></td> </tr> <tr> <td>No. of hours operation in a year</td> <td>=</td> <td>8400 hours</td> </tr> <tr> <td>Total heat loss (Kcal/yr)</td> <td>=</td> <td><math>43844 \times 8400 = 368289600</math></td> </tr> <tr> <td>Calorific value of fuel oil</td> <td>=</td> <td>10300 Kcal/kg</td> </tr> <tr> <td>Boiler efficiency</td> <td>=</td> <td>80%</td> </tr> <tr> <td>Price of fuel oil</td> <td>=</td> <td>Rs.15000/Tonne</td> </tr> <tr> <td>Yearly fuel oil savings</td> <td>=</td> <td><math>368289600 / 10300 \times 0.8</math></td> </tr> <tr> <td></td> <td>=</td> <td>44695 kg//year</td> </tr> </table>	Pipe dimension	=	100 mm $\phi$ & 100 m length	Surface area existing (A1)	=	$3.14 \times 0.1 \times 100 = 31.4 \text{ m}^2$	Surface area after insulation (A2)	=	$3.14 \times 0.23 \times 100 = 72.2 \text{ m}^2$	Total heat loss in existing system (S1 x A1)	=	$2500 \times 31.4 = 78500 \text{ Kcal/hr}$	Total heat loss in Modified system (S2 x A2)	=	$480 \times 72.2 = 34656 \text{ Kcal/hr}$	Reduction in heat loss	=	$78500 - 34656 = 43844 \text{ Kcal/hr}$	No. of hours operation in a year	=	8400 hours	Total heat loss (Kcal/yr)	=	$43844 \times 8400 = 368289600$	Calorific value of fuel oil	=	10300 Kcal/kg	Boiler efficiency	=	80%	Price of fuel oil	=	Rs.15000/Tonne	Yearly fuel oil savings	=	$368289600 / 10300 \times 0.8$		=	44695 kg//year
Pipe dimension	=	100 mm $\phi$ & 100 m length																																						
Surface area existing (A1)	=	$3.14 \times 0.1 \times 100 = 31.4 \text{ m}^2$																																						
Surface area after insulation (A2)	=	$3.14 \times 0.23 \times 100 = 72.2 \text{ m}^2$																																						
Total heat loss in existing system (S1 x A1)	=	$2500 \times 31.4 = 78500 \text{ Kcal/hr}$																																						
Total heat loss in Modified system (S2 x A2)	=	$480 \times 72.2 = 34656 \text{ Kcal/hr}$																																						
Reduction in heat loss	=	$78500 - 34656 = 43844 \text{ Kcal/hr}$																																						
No. of hours operation in a year	=	8400 hours																																						
Total heat loss (Kcal/yr)	=	$43844 \times 8400 = 368289600$																																						
Calorific value of fuel oil	=	10300 Kcal/kg																																						
Boiler efficiency	=	80%																																						
Price of fuel oil	=	Rs.15000/Tonne																																						
Yearly fuel oil savings	=	$368289600 / 10300 \times 0.8$																																						
	=	44695 kg//year																																						

<p>4.</p>	<p>List out the general requirements of refractory?</p> <p>The general requirements of refractory before selecting for any furnace are:</p> <ul style="list-style-type: none"> <li>i) Area of application</li> <li>ii) Working temperatures</li> <li>iii) Extent of abrasion and impact</li> <li>iv) Structural load of the furnace</li> <li>v) Stress due to temperature gradient in the structures and temperatures fluctuations</li> <li>vi) Chemical compatibility with the furnace environment</li> <li>vii) Heat transfer and fuel conservation</li> <li>viii) Cost considerations</li> </ul>
<p>5.</p>	<p>What are the factors involved in selecting a lagging material?</p> <p>The ultimate choice of a thermal insulating material is an engineering decision involving a number of factors, important among such are:</p> <ul style="list-style-type: none"> <li>1. The operating temperature of the system</li> <li>2. Thermal conductivity of the insulation</li> <li>3. Capability of the insulation in application to hot surfaces readily and cheaply</li> <li>4. Resistance to heat, weather and adverse atmospheric conditions</li> <li>5. Ability to withstand vibration, noise, and accidental mechanical damage</li> <li>6. Resistance to chemicals</li> <li>7. Resistance to fire</li> <li>8. No shrinkage or cracking during use</li> <li>9. Jacketing the insulation</li> <li>10. Total cost including maintenance costs</li> </ul>