Processing of Non-Metals
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Module - 2
Glass: Properties and Processing
Lecture - 3
Glass Processing – II

A warm welcome to all of you in this last lecture on glass processing. As you are well aware that now we are discussing module number two of our course processing of non-metals in module number 2. We have already seen or we already discussed two lecturers: In lecture number one, we have seen the glass, its structure, its history and the properties. And in lecture number two if you remember, we have seen that what are the basic processing steps in forming or manufacturing or processing or development of parts or products made up of glass.

We have also seen two of the important types of glass, which are made by the primary processing techniques. So, the two types of techniques we have seen, we have discussed that how a flat glass can be manufactured, we have seen the float glass technique, we have also seen the rolling or drawing in which a flat glass can be made. We have also seen how the glass filaments can be made, also towards the end we have seen how the glass wool is made. So, basically in lecture number 2 our focus was on processing of glass, in lecture number 1 our focus was on the structure and properties of the glass. So, we have already covered the basic aspects of the glass and the basic aspects of the processing of glass.

In today's lecture, our focus would primarily be on processing aspects in which, today I will discuss about the melting furnaces, which are used for melting the raw materials if you remember in lecture number 2 of this particular module. I have told that if the time permits we will have a brief overview of the types of furnaces, which are used for melting the raw material in order to process the glass products. So, there are basically four types of furnaces, which we would be seeing then, we will carry forward our discussion towards the processing of glass in which we will cover at least two different types of processes which are used for forming the glass products and finally, we will see the basic aspect of annealing, that how annealing is done in order to reduce the induced stresses, because of the processing steps or because of processing whatever, stresses are

induced in the product how they are relief.. So, that is the last part of today's lecture and the last part of this module also, that is the process of annealing. Now, we will start our discussion with revising or by seeing that what are the primary processing steps in case of forming of glass or processing of glass.

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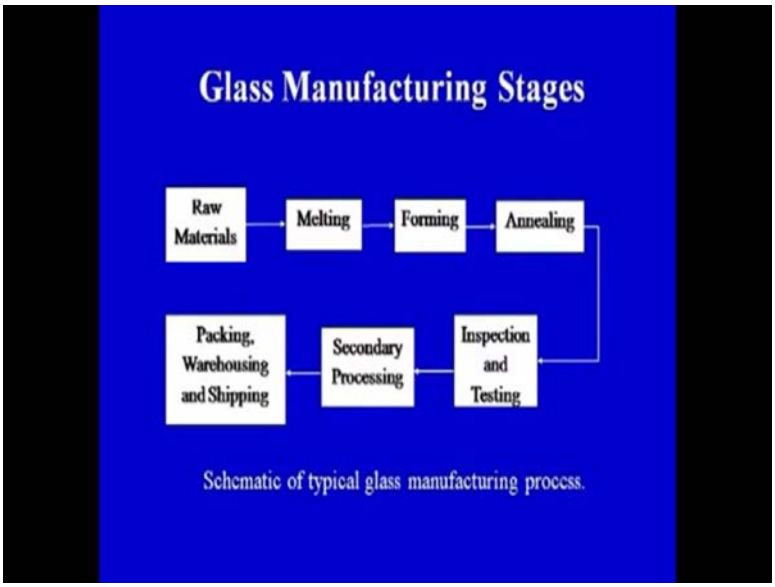

On your screen you can see, this is the diagram that we have already seen or this is a figure which was already covered or discussed in lecture number two of this particular module but, again we can revise that, what are the various processing steps, which are involved in making products out of glass. So, first of all we have the raw materials. Now, what are the various types of raw materials? how they are blended together or what are the various functions of the various raw materials or the constituents that go into the processing of glass, because you know that there are colorants and there are the basic materials, which we have already covered in lecture number 1, in which we have seen, that different types of raw materials or different forms of raw materials are combined together in order to process the glass product. So, we have already seen that, what are the various types of raw materials and how the glass is named after the types of raw materials which have been used to process that glass. So, the raw materials are there, these particular raw materials are melted. Today we will see that, which are the various types of furnaces? Which are used for melting the raw materials? So, we have set raw materials, we have definite proportion a defined proportion of the various constituents

which are combined together and finally, these are melted using different types of furnaces.

Once the melt has been made or the glass melt is ready. It is formed to give the desired shape if you remember lecture number 2, we have seen two methods of making the flat glass, in which a ribbon of glass was made to float over the bath of a very low melting point alloy such as tin and then, this is cooled under the controlled atmosphere. It is heated and cooled under the controlled atmosphere and a flat glass is manufactured. How that flat glass is better as compared to we can say a different types of other glasses, which are not of good quality, because the glass that is coming out of this particular process is uniform in thickness and it has got very good surface finish and we need not do any finishing operation or grinding operation on this glass, because of the very good surface finish that we achieve. So that type of processes fall under the forming, we have also seen rolling or drawing in which the flat glass is rolled out between the two water cooled rollers, which these two processes were discussed in lecture number two, also we have seen the glass can be formed into very fine filaments. So, the order of diameter of two micron. So, how those filaments can be formed through the orifice, the molten glass is made to be drawn out and depending upon the diameter of the orifice the diameter of the glass filament is made. So, we have seen that to the tune of two micron, we can get the diameter of the glass filament. So that is falling under the forming process.

Initially, we have a raw material, we are melting the raw material and after melting we are forming the raw material in this case is glass. So, we have the raw material, it is melted. We will see, what are the types of furnaces used and finally, it is formed for forming, we have already seen that, there are number of processes at least two or three processes we have seen in lecture number 2 and today also we are going to see some of the processes which are used for forming the melt into the exact product or the final glass product, which would be put to use or which is our final application. So, after melting, we form the glass after forming the annealing is done, because the induced stresses of processing because of processing there may be certain induced stresses in the final product and those stresses have to be relived and therefore, we carry out the annealing process.

So, technically these are the four important points to convert the glass raw material into the final product but, after the product has been made, it has to be inspected and tested, it

has to undergo certain secondary processing steps and finally, it is ready for packaging ware housing and shipping. So, all these three points, we have seen we have also seen that, what are the major type of secondary operations which are done on glass in the previous lecture but, today our focus is on the first four steps only, that is we have set of raw materials. The raw material is melted in different types of furnaces then, the molten glass is deformed or given a form using one or the other technique and finally, once we get the product. It is annealed to reduce the induced stresses. Now, let us start our discussion about the furnaces or the step two of this diagram that, what are the, which are different types of furnaces, which are used to the melt the raw material.

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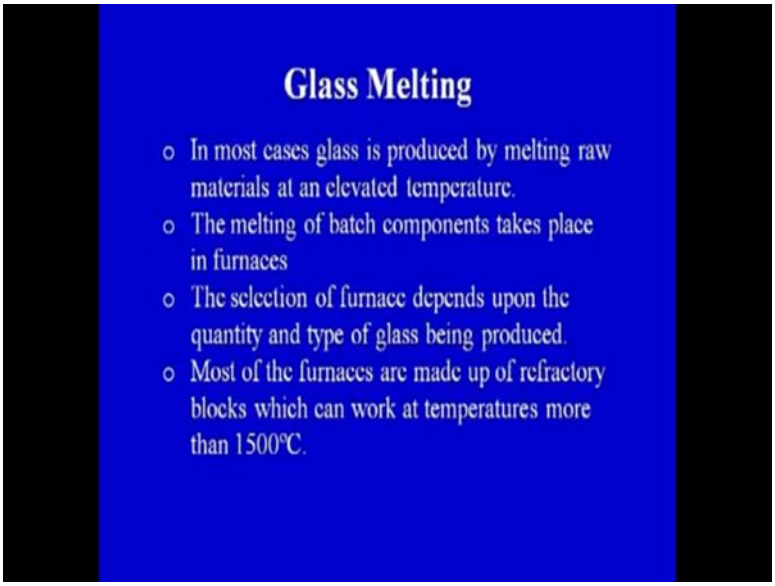

Glass melting in most cases glass is produced by melting raw materials at an elevated temperature which is very very clear that at a high temperature. We will melt the glass; the melting of batch components takes place in furnaces. Now, batch component means, the constituents the batch of the constituents suppose, we want to make a particular type of a glass. So, we will make the chosen the constituents accordingly and this particular batch will go for melting at an elevated temperature.

The selection of furnace depends upon the quantity and type of glass being produced. So, once we have the batch components ready, that is the constituents that will go into the final product or the constituents that would form the raw material. Once that batch is ready then, it is melted and once it is melted the molten glass is then, formed using any

of the techniques which we already discussed or some of the techniques that, we are going to discuss in today's lecture.

So, the selection of the furnace depends upon the quantity and type of the glass being produced. Now, we have to see that, how much glass we want to produce? What is the quantity and what is the type. So, depending upon the type and quantity of the glass which has to be produced the particular type of furnace would be selected for that particular application. So, the criteria majorly are the quantity and the type of the glass.

Now, most of the furnaces are made up of refractory blocks, which can work at a temperature more than 1500 degree centigrade. So, the temperature of operation is generally more than 1500 degree centigrade per most of the furnaces. So, in order to summarize the information about the melting of glass as on your screen you can see in most cases, the glass is produced by melting raw materials at an elevated temperature.

The melting of batch components takes place in furnaces and the selection of furnace depends upon the quantity and type of the glass being melted or produced and most of the furnaces are made up of refractory blocks, which can work at temperature at more than 1500 degree centigrade. So, we can see, that the melting is done at elevated temperature, batch components mixed with raw materials are constituents are club together or there mixed together finally, they are grinded to the melting operation and the melting or the type of furnace depends up on the type of the glass being melted and the volume of or the total weight of the glass being melted or in other words, we can say the quantity of the glass is being melted and finally, the furnaces are usually made up of refractory blocks and the temperature can go up to 1500 degree can be more than degree centigrade.

Now, with this background in which, we have to melt the raw material using any of the furnaces. There are different types of furnaces, which are available with the engineers to choose from. Now, what are the various types of the furnaces and which are the various types' furnaces which are available.

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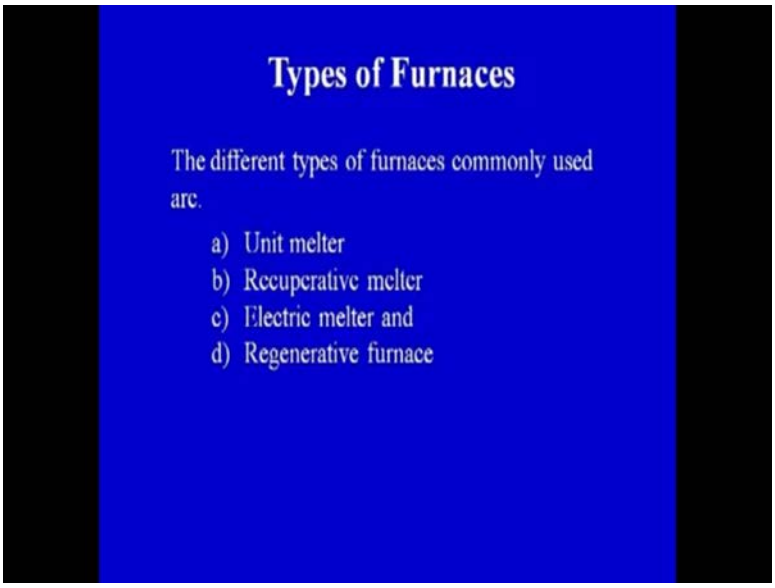

On your screen we can see there can be a unit melter recuperative melter, electric melter and regenerative furnace. So, there are different types of melter and furnaces, which are used for melting the raw materials once again, we can see you can keep these thing in your mind there can be a unit melter, there can be regenerate melter, there can be a electric melter or there can be a recuperative melter.

Now, briefly we will see that, what are these four types of melting techniques or melting methods for melting the raw material? What is the salient feature of these melters?

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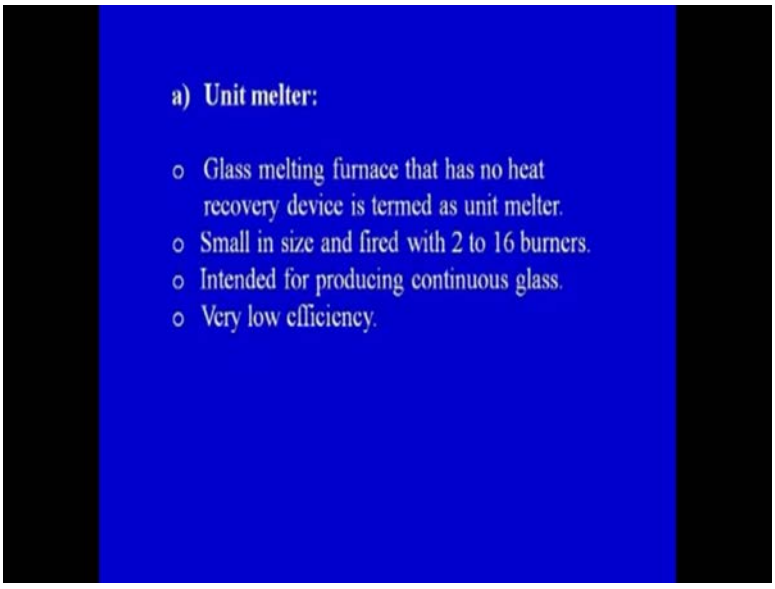

So, first one is the unit melter a unit melter glass melting furnace that has no heat recovery device is termed as unit melter. So, there is a no a heat recovery where as in other types of melters we will see that, there is a heat recovery small in size and fired with 2 to 6 burners. So, that number of burners that are used for generating the heat may range from 2 to 16, it is intended for producing continues glass. So, when we have to produce any of the technique where continues production of glass is required and there are the unit melter is of best use.

And the efficiency is low, why? Because we are not able to recover. So, in case of no heat recovery is there the efficiency is the lower. So, in order to revise what is there in a unit melter that we should keep in mind, that it is used for continues glass manufacturing, the efficiency is not very high as well as the heat recovery is also not there. It is small in size and the number of burners that are there may range from two to sixteen. So, this type of furnace is a small in size furnace and is used for continues glass manufacturing.

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The b is the recuperative melter a recuperative melter is a type of unit melter in addition with the recuperater. So, here we have recuperater, which is not there in case of a unit melter, otherwise it is similar to unit melter only. It is less energy efficient than regenerative furnace. So, energy efficiency will be more than the unit melter but, is less than the regenerative melter that we are going to see in this subsequent slide. The furnace is used most often for textile fibre glass production. So, it has specific applications, also

although it can be used for other areas also but, specifically it is used for textile fibre glass manufacturing. So, where ever the textile fibre glass has to be manufactured, we can choose recuperative melter.

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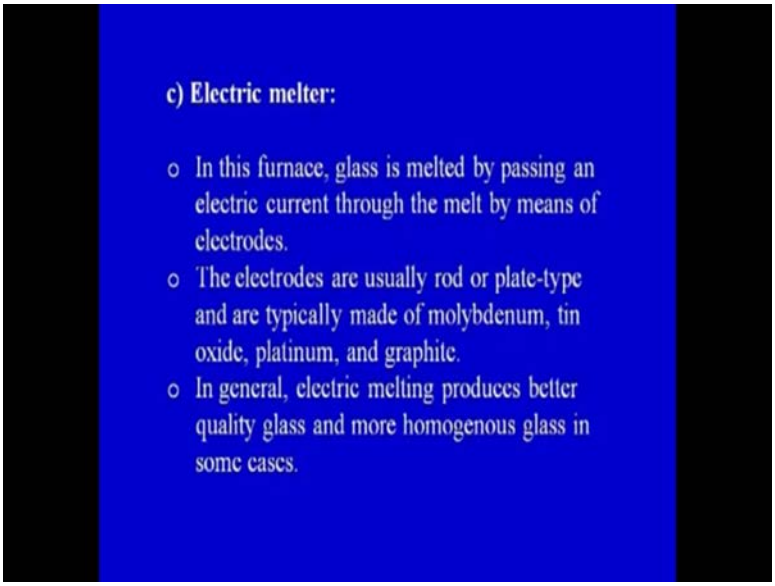

Electric melter in this furnace glass is melted by passing an electric current through the melt by means of electrodes. So, here the electrodes are placed and the current is used to generate the heat. So, glass is melted by passing and electric current through, the melt by means of electrode the electrodes are usually, rod or plate type and a typically made of molybdenum tin oxide platinum and graphite. So, we have seen in this particular slide that, what are the various types of materials which can be used for making the electrodes? Which are going heat the glass raw material in order to melt the raw materials?

So, the different types of electrode materials can be again you see on your screen, it is molybdenum tin oxide platinum or graphite. So, these are the materials of the electrodes, which are used in the electric melter for heating up the by the flow of current. So, the heating is done with the flow of electric current in general electric melting produces better quality glass and more homogeneous glass in certain cases. So, the quality of the glass that we will get in case of electric melter is much better as compared to the other types of melter. So, the quality of the glass is better and more homogeneous glass is made using the electric melter. So, what are the salient features of the electric melter, the

source of heat in this case of flow of electric current which melts the raw materials to make the glass melt.

Secondly, rod or plate type of electrodes are used the material of the electrodes is molybdenum tin oxide platinum or graphite more over. It produces a very good quality glass and a homogeneous glass. So, electric melter has got its own advantages as compared to the unit melter and the recuperative melter.

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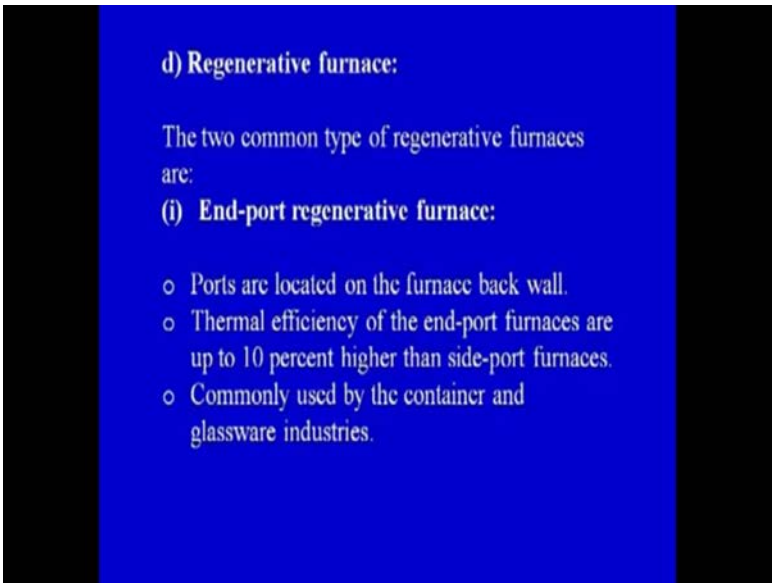

Finally, we have the regenerative furnace. Two common types of regenerative furnaces are end-port regenerative furnace and the side-port regenerative furnace that we are going to see in the subsequent slides.

So, in case of end-port regenerative furnace ports are located on the furnace back wall end-port ports are at the end or at the furnace back wall. Thermal efficiency of end-port furnaces are up to ten percent higher than the side-port furnaces. That side-port furnaces the ports are on the sides of the furnace and the efficiency of end-port furnace or you can say, the port is towards the back wall of the furnace the efficiency is ten percent higher than the side-ports finally, commonly used for container and glassware industries.

So, this regenerative end-port regenerative type of furnaces is used for containers making of containers or where the glassware is being made. So, depending upon the position or the placement of the ports the regenerative type of furnaces can be classified into two

categories, category number one is a regenerative type of furnace end-port regenerative type of furnace and second category is the side-port regenerative type of furnace.

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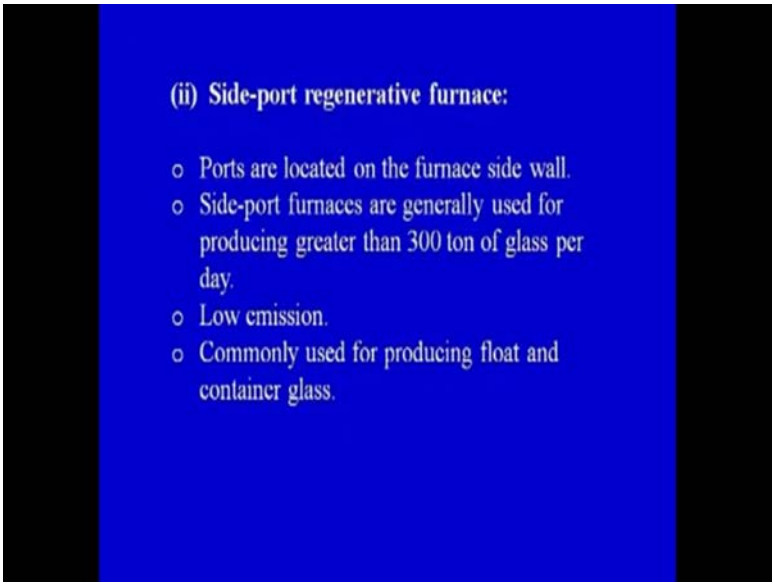

So, on your screen you can see, we have a side-port regenerative furnace, in side-port regenerative furnace ports are located on the furnace side wall in case of endport type of regenerative furnace the ports were located at the back wall (refer time: 18:00) here the ports are located on the side wall, side-port furnaces are generally used for producing greater than 300 ton of a glass per day. So, we can see the production rate of side-port type of regenerative furnaces. Also, given the emissions are low. So, it is environment-friendly and commonly used for producing float and container glass.

So, we have seen the float glass process in our previous lecture that is lecture number 2, in module 2, we have seen how a float glass method is used to produce the flat glass. So, this type a furnace side-port type of regenerative furnace can be the melting source in case of the float glass type of process. So, we have seen that, the glass is melted and there are different types of melters which are used, we have seen there is unit melter, which is small in size then, we have seen there is a recuperative type of melter then, the we have seen electric melter and finally, we have seen the regenerative type of furnace. So, all these four types of melters and furnaces can be used to melt the raw materials. Now, once we have the raw material, we have decided on the constituents are the proportions of the constituents that will go into the raw material, that particular stage has

been achieved. We will use that batch component into the furnace and the furnace then, we will be used depending upon the requirement that for which particular industry. We are going to melt the glass or what has to be made finally, out of that glass we will choose the type of the melter or the furnace and where we will put our raw material. Now, the raw material would be melted.

So, two stages we have seen that, the formation or manipulation of the raw material and secondly the melting of the raw material by any of the melter and finally, whatever we have got in the form of the molten glass has to be given a desired shape and that shape would dictate the use of that particular product suppose, you want a flat glass, we can have a glass tubing, we can have a glass filament or fibre we can have a glass wool. So, depending upon the final form of the glass, that we want to achieve, we will now form the molten glass into that desired shape.

So, for that, we have a number of processing techniques, which we are covering as a part of this particular module if you remember in lecture number 2, we have seen methods to make flat glass, we have also seen methods to make glass filament and glass wool. So, today our focus is to see that, what are the other processing techniques to generate different types of shapes? We will also see that, there are some specific applications of glass or specific types of glasses which are used for very specific applications, such as laminated glass then, we can have toughened glass.

So, this toughened and laminated glass, we are going to cover today that, what do we mean by a laminated glass, what do we mean by a toughened glass, all that we are going to see if you remember in lecture number 2, we have seen patterned glass, we have also seen in which a type of a glass in which, there was a wire which was there. So, different types of glasses are there, maybe there are more than five hundred different types are uses of glasses, which we see in our day today life.

So, now we will focus on the processing of molten glass into the desired shape, we have already covered the raw materials in lecture number 1, we have covered the processing techniques in lecture number 2. Today, we have seen the different types of melters, which are used to melt the glass into the molten glass and now we will see some of the techniques which are used to produce the shapes of the glass products.

Now, one of the important two techniques, we have see written in this particular slide, because a and b two impotent techniques we have covered in lecture number 2, in which we have seen, how to make a flat glass and how to make a glass filament or a glass wool. So, two techniques we already covered in lecture number two, this is a third technique to give a shape or to form a shape of the molten glass, the molten glass we have got from any of the melters that we have already discussed earlier.

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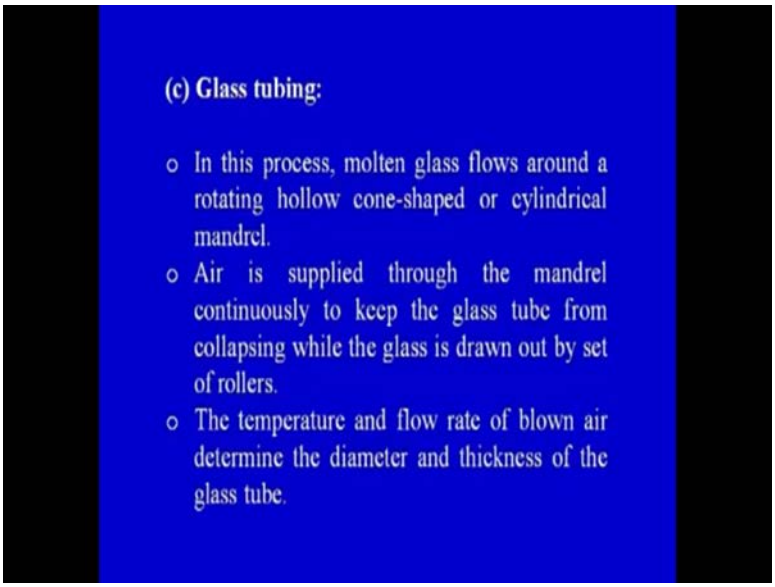

So, in glass tubing in this process, molten glass flows around a rotating hollow cone shaped or cylindrical mandrel. So, the mandrel is there as in case of metals whenever we have to make a tube, we use a mandrel. So, similarly, in glass tubing also we have to use a mandrel. So, in this process, the molten glass flows around a rotating hollow cone shaped or cylindrical mandrel, we will try to see this with the help of diagram also but, let us see that, they what are the terms which will be used in the diagram. So, we have a rotating mandrel and the molten glass flows over the rotating mandrel.

Air is supplied through the mandrel continuously to keep the glass tube from collapsing while the glass is drawn out by the set of rollers. So, when the glass is coming out and it is drawn out by the set of rollers there is a tendency that, the glass may join together or there are chances that are the glass tube may collapse. So, in order to avoid the collapsing action continues jet of air is passed through or through the mandrel. So, that the glass does not collapse and the inner diameter is maintained. So, the temperature and

the flow rate of the blown air determine the diameter and the thickness of the glass tube. Now, the air jet that is blown out, the temperature and flow rate of the blown air. Now, this will have it is influence or this will dictate two important features of the glass tube. Now, what are these two important features? The two important features of or the geometrical features of the glass tube are. So, what are these features? These features are the diameter of the tube, that we are going to get and the thickness of the glass tube wall.

So, these are two things, which would be controlled by the temperature and the flow rate of the air that is flowing through the mandrel. Now, let us try to understand this particular process with help of a diagram.

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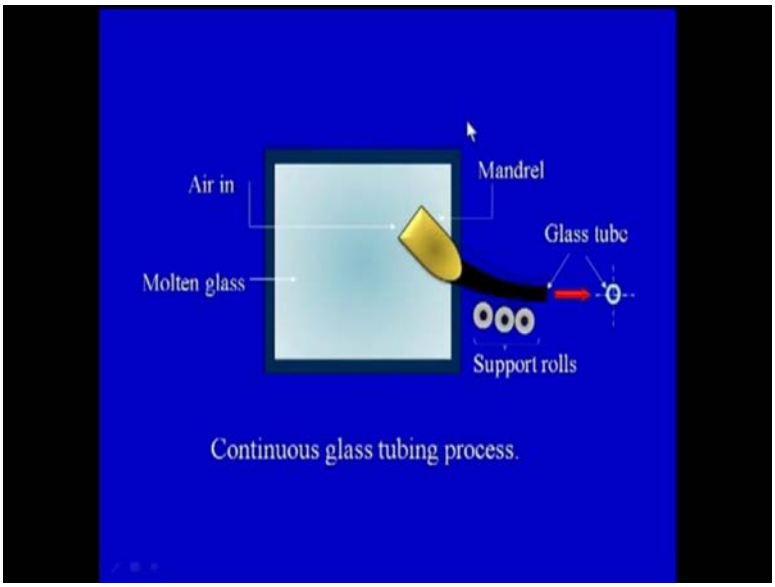

On your screen you can see a simplest simplistic are a very easy representation of the process, we have a molten glass of this particular colour represents the molten glass, this is the mandrel and in this mandrel we have a air is being blown through this mandrel and this is the glass tube, black colour portion this is the glass tube which is coming out, this is the cross section of the glass tube, it is hollow from inside you can see. It is hollow from inside and it has got a wall thickness and these are the supporting rollers that support the glass tube, which is coming out of this container, which contains the molten glass. So, we have seen in the previous slide that, there is a mandrel, this the mandrel, this is the molten glass or the raw material there is a air inlet, which will be blowing out from here and it will dictate the diameter of the tube glass tube as well as thickness of the

hole or thickness of the wall of the glass tube. So, here we can see, this is the cross section of the glass tube, which has been produced. It is hollow from inside the final diameter outer and inner diameter would be controlled specifically, the inner diameter will be controlled by the rate at which is the air is blown and secondly the thickness of the wall would be controlled by the blown air. So, there are supporting rollers also. So, this is one of the important techniques of making the tubes out of the molten glass.

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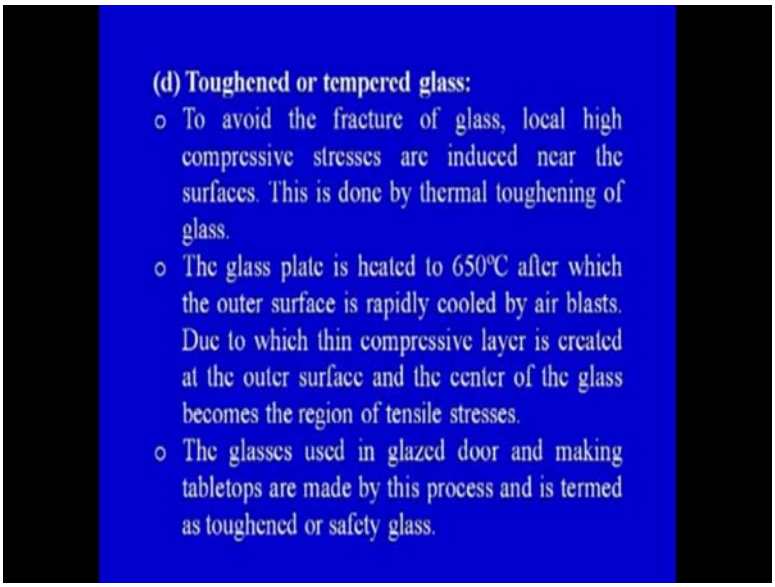

Now, toughened or tempered glass. Now, this is another category of the glass, which is used for specific application, we can see that, we have the glass tubing, we have seen flat glass, we have also seen glass filaments or fibre we have seen glass wool. Now, there is another category of glass that is toughened or tampered glass. Now, why do we need to do the toughening or tampering of the glass, we can see to avoid the fracture of glass local high compressive stresses are induced near the surfaces; this is done by thermal toughening of the glass. So, what does this mean? this mean that, if we want to avoid the fracture of the glass, we need to have compressive stresses at the surface and the tensile stresses in between therefore, you can see to avoid the fracture of the glass local high compressive stresses are induced near the surface, this is done by thermal toughening of the glass.

Now, how thermal toughening is done, that we can see the glass plate is heated at 650 centigrade, after which the outer surface is rapidly cooled by the air blast. Now, we have

seen that, the outer surface of the glass plate the glass plate can be manufactured by any method. Now, the glass plate is heated to 650 centigrade, after which the outer surface is rapidly cooled, how it is cooled? It is cooled by the air blast. So, the air blast will cool the surface of the flat glass or the glass plate which has been heated up to 650 centigrade, due to which thin compressive layer is created at the outer surface and the centre of the glass becomes the region of tensile stress. So, at the surface we will have the compressive stresses at the centre, we will have the tensile stresses at the surface, when we have a compressive stress the glass will be toughened. Now, this type of glasses are used in glazed doors and making table tops and this process is termed as toughening or the safety glass this type of glass is called the toughened or the safety glass.

So, very broadly or summary, we can have of this particular process that we have a flat glass plate or sheet and this particular glass plate is heated to six fifty degree centigrade at the surface and then it is cooled with the jet of or the air blast and once it is cooled this heating and cooling will make the compressive layer very thin compressive layer on the surface at inside there would be tensile stresses and this particular type of glass which has under gone this particular cycle of heating and cooling is called the toughened glass and it has applications in making glazed doors and table top the glass that we use on the table top that type of glass can be made by subjecting it to a higher temperature and then cooling the surface by using the air blast.

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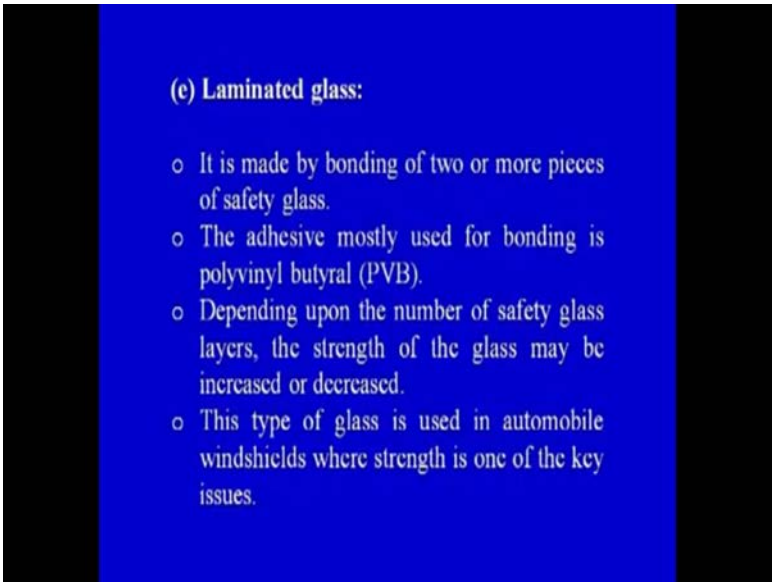

Then, we have a laminated glass, what is laminated glass? It is made by bonding two or more pieces of the safety glass; in the previous slide we have seen the toughened or safety glass. How it is made? It is subjected to a higher temperature and finally, that higher temperature is brought down with the help of air blast at the surface, we have the compressive stress in between the glass plate we have the tensile stress and this type of glass is called the toughened or the safety glass.

So, this type of safety glass is again use for making the laminated glass, it is made by bonding two or more pieces of the safety glass. The adhesive most commonly used for bonding is polyvinyl butyric p v b, depending upon the number of safety glass layers; the strength of the glass may be increased or decreased. Now, depending upon the numbers of layers in the laminate the strength of the particular glass can be either increased or it can be decreased. The type of glass is used in automobile windshield where, strength is one of the key issues. So, laminated glass is used in many of the automobiles as the windshields, So, we have seen that, what is toughened or safety glass and we have also seen what is the laminated glass. So, laminated glass is nothing is there are different layers which are stacked up together. Now, individual layers are made up of the safety glass and the depending upon the strength requirements, we will decide upon the number of layers, that we have to stack up in order to make a laminated glass and in between we use a adhesive and the type of adhesive is p v b as it is given on the screen.

Then, there are types of specific glasses which are used for specific applications which are the tinted glass, coated glass and self cleaning glass.

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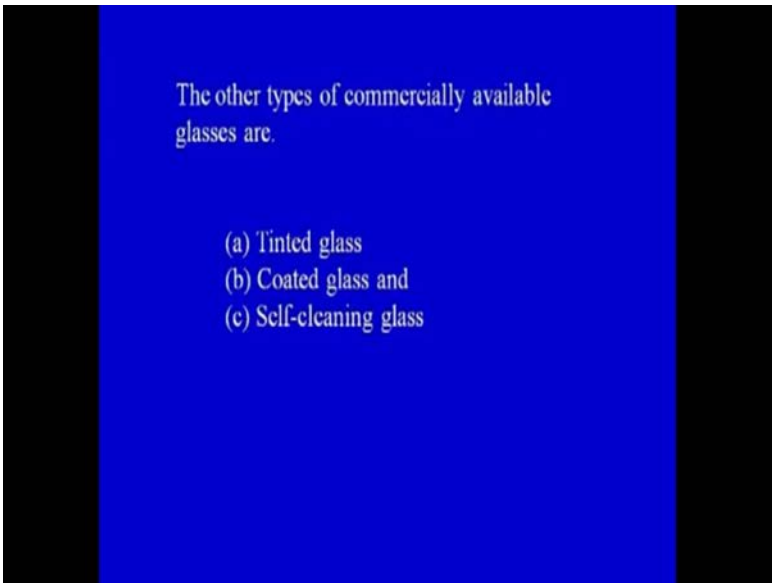

So, we will very briefly see that, what are the tinted glass or the coated glass and finally, the self cleaning glass.

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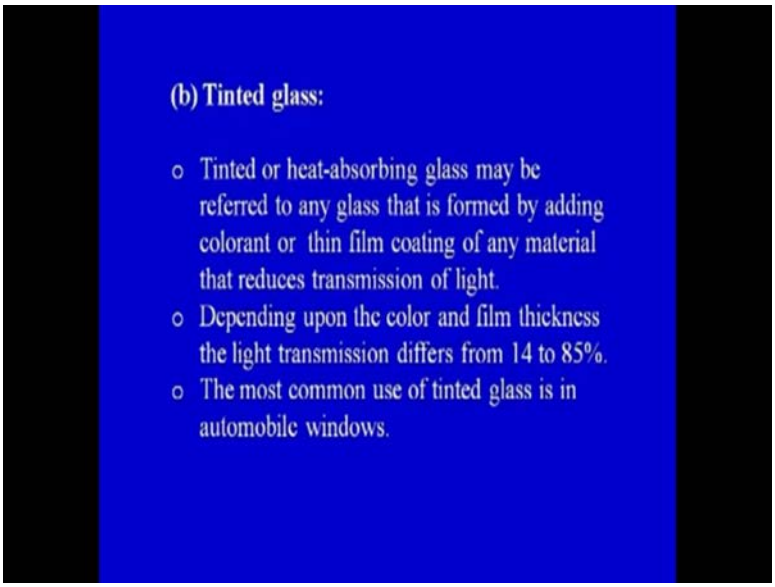

Tinted glass tinted or heat absorbing glass may be referred to any glass that is formed by adding colorant or thin film coating of any material that reduces transmission of light. So, basically we want to reduce the transmission of light through the glass and therefore, it would be tinted with certain colorants or certain films. So, tinted or heat observing glass may be referred to glass, that is formed by adding colorant if you remember in the

very first lecture, we have seen there are different types of constituents that go into the raw material which is finally, melted to make the glass. So, one of the important constituent was the colorant. So, in tinted glass we are adding the colorant why, we are adding the colorant, because we want to make a particular type of a glass. So, that the transmission of light is reduced through that particular glass. So, we can either use a colorant or a thin film coating of any material that reduces the transmission of light. So, the basic purpose of using tinted glass is that it should not allow the transmission of light.

Now, depending upon the colour and film thickness the light transmission differs from 14 to 85 percent. So, that is the level of opacity to light that we can achieve by adding different types of colorants or by putting different types of thin films. So, depending upon the colorant, the film thickness of the light transmission differs from 14 to 85 percent. The most common use of tinted glass is in the automobile windows as most of us we know, we see the different types of films are used by people for objecting or for reducing the transmission of light through the windows.

So, summarizing the use of the tinted glass, the most common use of tinted glass is in the automobile windows. So, we have seen different types of films are put in the automobile windows to reflect and reduce the transmission of the light from outside to inside. So, different categories of glasses are there then, the last category is the coated glass, we are going to cover whatever possible different categories of glasses.

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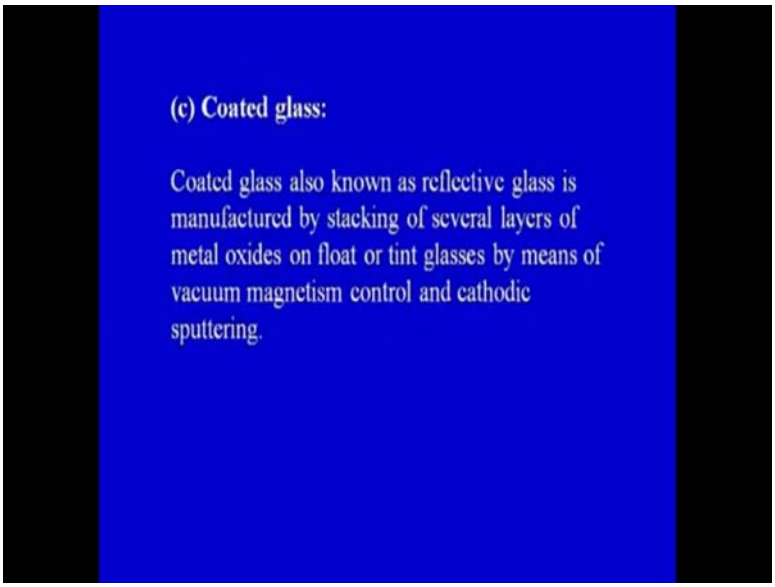

So, coated glass also known as reflective glass is manufactured by stacking of several layers of metal oxide on float or tint glasses by means of vacuum magnetism control and cathodic sputtering.

So, we are not going into the detail of the processes mentioned here, like the vacuum magnetism controlled over cathode or sputtering but, we are going to see focus on the application aspect of the coated glass that, this is made by stacking several layers of the metal oxides zone float or tint glass. So, we have seen in the previous slide what is the tinted glass is tinted glass, we are putting the type of colorant or thin film is put. So, that the transmission of light is reduced and the efficiency may vary from 14 percent to 85 percent. Now, if you use that type of a tint glass or different layers of tint glass are stacked together, we can get a coated glass.

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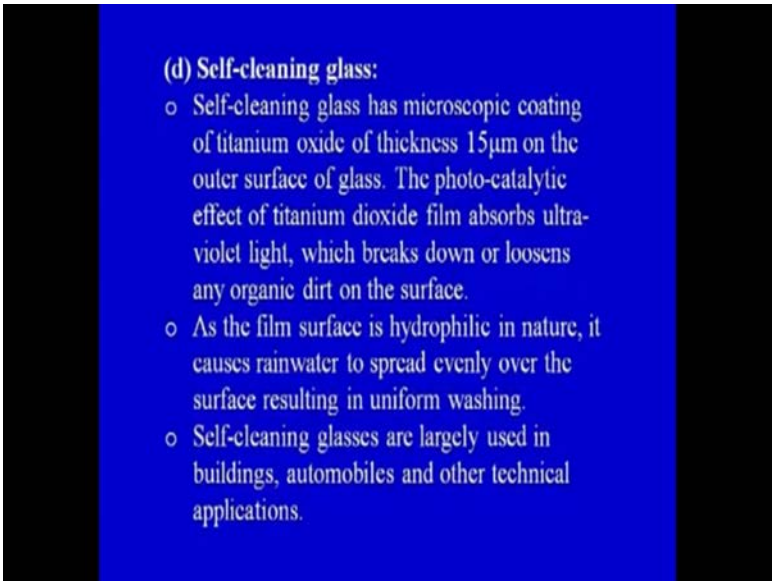

Another important category of glass is the self cleaning glass, in case of self cleaning glass we have a microscopic coating of titanium oxide, what is the thickness is fifteen microns on the outer surface of the glass. So, in self cleaning glass, we have a microscopic coating of titanium oxide of the thickness of fifteen micron and where is the coating, this is on the outer surface of the glass.

Why do we put this coating? The photo wall catalytic effect of titanium oxide film. So, we have a titanium oxide film coating of the order of fifteen micron on the outer side of glass why, we have put this thin film the photo catalytic effect of titanium oxide film

absorbs ultraviolet light which breaks down or loosens organic dirt on the surface. So, self cleaning means that, it has to remove the dirt from the surface or water droplets from the surface. So, how it cleans the dirt the photo catalytic effect of titanium oxide or absorbs ultraviolet light and which breaks down or loosen any organic dirt on the surface. So, this is the automatic cleaning or self cleaning of the glass similarly, as the film surface is hydrophilic in nature, it causes rain water to spread evenly over the surface resulting in a uniform washing. So, it does not, we can say allow the water to be there on the surface, because surface is hydrophilic in nature. So, the water is also cleaned as well as the dirt and dust is also cleaned from the surface of the glass.

Now, self cleaning glass is largely used in buildings automobiles and other technical applications. So, we have seen that, there are huge buildings which have a full outer covering of the glass and it is very difficult to clean those glasses and in this type of scenario or this specific application, self cleaning glass finds huge potential and application area. Now, we can just revise or just look at this particular slide again that, what are the basic mechanism of cleaning action in case of a self cleaning glass, a self cleaning glass has a microscopic coating of titanium oxide, the thickness of the coating is 15 micron on the outer surface of the glass, the photo wall, the photo catalytic affect of titanium oxide film absorbs ultraviolet light and which breaks down or loosens any organic dirt on the surface. So, organic dirt is cleaned, because of this photo catalytic action of the titanium oxide which absorbs the ultra violet light.

Similarly, because of the hydrophilic nature, it causes rain water to spread evenly on the surface resulting in uniform washing of the outer surface of the self cleaning glass and therefore, it finds the application in big buildings or automobiles and other specific applications.

Now, coming on to the last part of our lecture, let us first see, what we are covered today in today's lecture, we have seen very briefly. The different types furnaces or melters, which are used for melting of the raw materials in ordered to process the glass we have also seen how glass tubing can be made then we have seen what is toughened glass we have seen what is laminated glass and finally, some categories of specific categories of glasses, we have covered like the tinted glass and coated glass or the finally, just now we have covered the self cleaning glass. Now, once the raw material has been melted, the molten glass is then formed into the desired shapes. That we have already seen that, what

are the different types of glasses which can be used and finally, once products is ready there are certain times induced stresses in the products.

So, these stresses can be reduced and these thermal stresses can be induced by the process of annealing and final stage is the glass annealing stage in case of processing of glasses. So, in annealing what is done?

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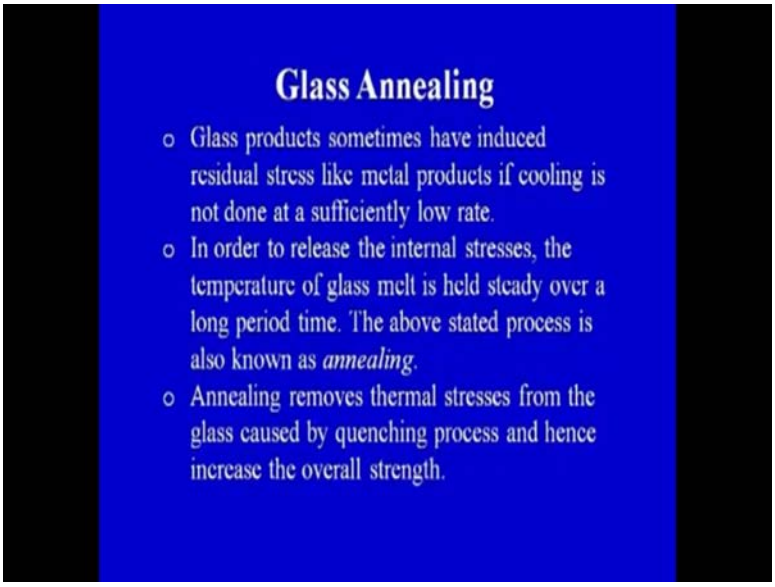

Glass products sometimes have induced residual stress like metal products if cooling is not done at a sufficiently low rate. So, the amount or the type of stresses that is developed and will depend on specifically on the cooling rate, we have to manipulate the cooling rate in such a way. So, that we do not get any stresses in the final product but, in many cases, because of the processing steps involved, because of the specific requirements of the product induced stresses are the found in the final glass products. So, the glass products some time have induced residual stresses as in the case of metals and these are there, because the cooling is not done at a particular rate or the cooling is not done at a sufficiently low rate in order to release the internal stresses.

Now, these internal stresses may later on lead to failure of glass product or the failure may not take place may be within the day's or we sit may take place after months also because of the internal stresses. So, in order to release the internal stresses that temperature of that glass melt is held steady over a period of long period of time. So, we

will is, what is the annealing cycle and how a annealing is done in case of glasses but, first of all we should try to understand that we heat the glass.

That particular glass level and then maintained there for a long period of time finally, cooled data specific cooling rate. So, in order to release the internal stresses, the temperature of the glass melt is held steady over a long period of time. The above stated process is also known as annealing. So, this is what, we are discussing specifically in case of glass products annealing removes thermal stresses from the glass caused by quenching process and hence increases the overall strength. So, we can see that, because of quenching or quick cooling sometimes, whatever stresses are developed, these can be relieved by the annealing process and the strength of the final product can be improved.

So, we have just seen that, what is the annealing process in case of glasses? Now, we our focus would be on the process description on your screen you can see that broadly there are four steps that are there in the glass annealing. Now, what are these four steps we will cover these steps one by one.

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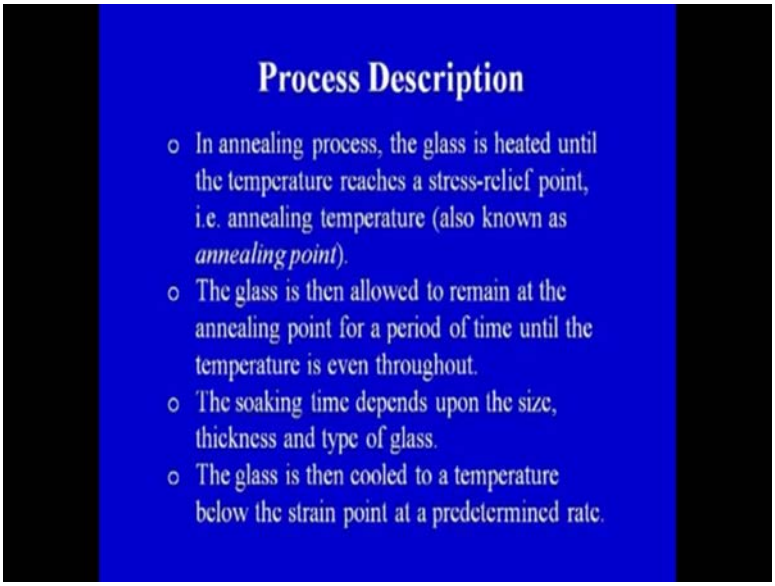

Now, step number one in annealing process the glass is heated until the temperature reaches a stress relief point that is annealing temperature also known as the annealing point.

So, first important point is to increase the temperature of the glass product to a particular level. Now, what is that level is called? That level is called the annealing temperature or the annealing point and what is going to happen at that particular point is also clear. It is a stress relief point. Now, whatever stresses are present in the glass product would be relived at that particular level. So, in an annealing process, the glass product is heated until the temperature reaches the stress reliving point that is annealing temperature. It is also called as the annealing point. So, once we have hated the or we have raised the temperature of the glass product to the annealing point or the stress relief point, we have to keep the product at that particular temperature for a prolonged period of time, which is mentioned in point number two. The glass product is then allowed to remain at the annealing point for a specific period of time until the temperature is even throughout means that, the total product has got the same temperature or we have different points within the product, which are at the same temperature. So, two important steps are heating the glasses is heated until the temperature this is the stress relief point and secondly, we are maintaining the level at which we have raise the temperature.

Third period, the soaking time or this holding time, we can also call this time as the holding time. The soaking time depends upon the size thickness and type of the glass. Now, this will depend because in the previous point, we have seen that the temperature is even throughout. So, we have to maintain this particular condition, that we have a uniform temperature throughout the product. So, if the size is very very big, the time would certainly more, because it will take longer time to reach the same temperature at each and every place. So, the soaking time depends upon size of the product, it will also depend upon the thickness and finally, it will depend upon the type of the glass.

So, it make depend upon the sectional thickness of minimum or maximum sectional thickness and it will depend on and which type of glass we are doing the annealing process. So, we have raise the temperature to a particular point the point is called the annealing point suppose, there are other names also for that point then, we are maintaining that temperature and finally, the glass is cooled to a temperature below the strain point at a predetermined rate. So, this cooling is also predetermined, the rate at which the cooling will take place is also predetermined. So, we can try to understand this with help of very simple diagram on your screen.

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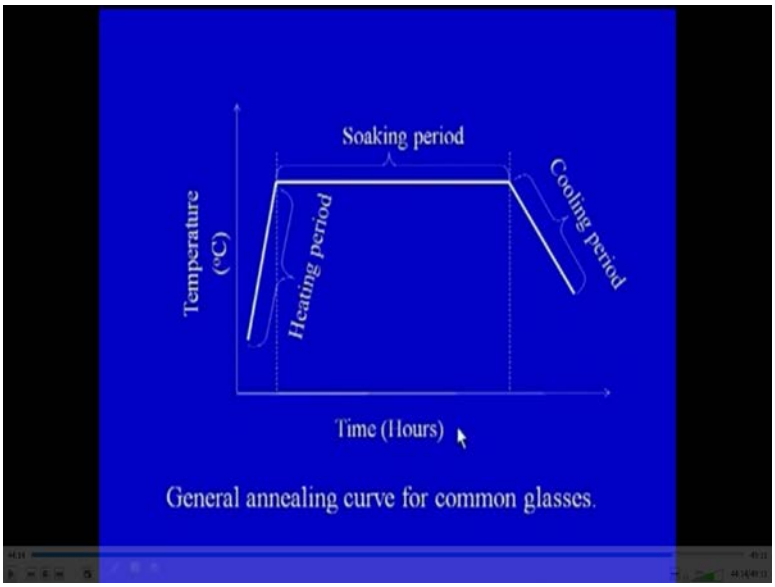

We have on y axis, we have the temperature and on x axis, we have the time. We can see when, we start from a particular temperature the temperature is increased linearly to a particular time and this is the soaking period first one is the heating period, in which the temperature of glass is increased and finally, it is kept at the same temperature for a long period of time, that is called the soaking period and once the stresses have been relived finally, it would be cooled at a predetermined cooling rate.

So, this is the general annealing curve for common glasses. So, for most of the glasses this would be the type of curve, which would be used but, certainly if you see on y axis we do not have any scale, there is no mention of the temperature. Now, depending upon the type of the glass, the size of the glass product or the sectional thickness of the glass further temperature may vary. So, that temperature may vary but, the basic nature of the glass annealing curve would be same in which first the temperature would be raised, which is called as heating period.

Then, it will maintain for a particular specific time, that is soaking period and finally, the cooling would take place. So, primarily the focus would be to reduce the stresses that are developed in the particular product, because of the processing if you remember in processing we are melting the glass at a very high a temperature and this molten glass is being formed into the desired shapes, the shape may be a flat glass, it can be a tubing, it can be a filament or it can be a glass wool.

So, at high temperature, the processing is taking place and therefore, the there are stresses in the final product and this particular product or the glass has to be annealed in order to reduce those stresses and this is the final process of getting a product out of glass and once we have we made this product after being annealed, it will be tested and inspected after testing and inspections certain secondary operations would be conducted on this particular product and finally, it would be shifted. So, if you remember just to summarize the various stages or various steps in the processing of glass products, initially we have the raw materials, the raw materials are the melted after melting the molten glass is formed into the desired shapes and once the forming has taken place, we get the final product. It is annealed in order reduce the induced stresses and finally, we do the secondary operation and the glass is ready for or the glass product is ready for use.

With this we come to the end of module number 2, in which we have seen 3 lectures, lecture number 1 in which, we have seen glass structure and its properties, in which we have seen, what are various types of glasses and what are the various constituents that go into the manufacturing of glass product. In lecture number 2, we have seen the basic processing steps involved in making a glass product and we have seen two important types of glasses, that are made, that is the flat glass as well as we have seen the glass filaments or fibre and the glass wool that, how these types of glasses glass products are made.

And in today lecture, we have seen that, what are the various types of furnaces or melters, which are used to melt the raw materials and we have seen that, how glass tubing is made, also we have seen what is the toughened glass, laminated glass, coated glass, self cleaning glass and finally, we have seen that, once the glass product is manufactured how it annealing process is done and the various terms that are associated with the annealing process in our subsequent lecture, we would keep on focusing on the various processing techniques for other types of non-metals.

Thank you.