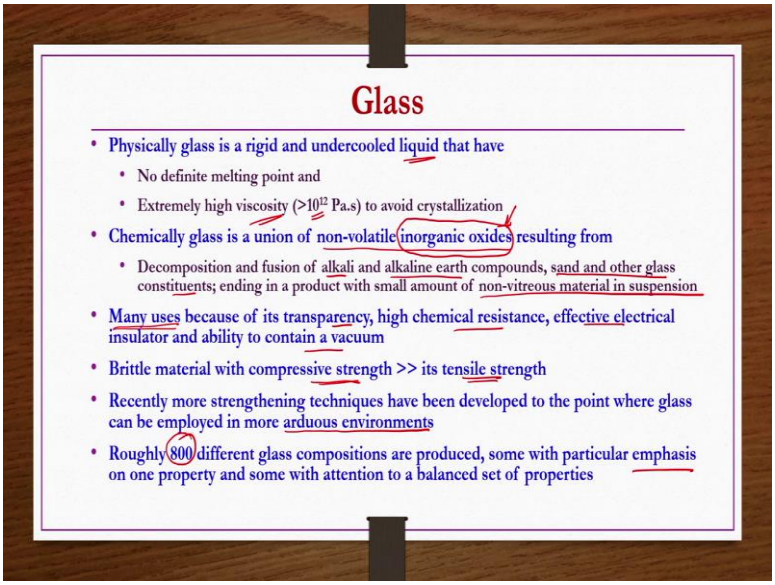
Inorganic Chemical Technology
Prof. Nanda Kishore
Department of Chemical Engineering
Indian Institute of Technology, Guwahati

Lecture - 27
Glass Industries

Welcome to the MOOCs course Inorganic Chemical Technology, the title of today's lecture is Glass Industries. Before go into the details of glass industries, what we will see will have a kind of a definition of what is a glass.

(Refer Slide Time: 00:44)



Physically it is a rigid and under cooled liquid that have no definite melting point because it is not a single component, it is a mixture of several components and their composition variations are also so many that hundreds of types of glasses are being produced. That is the reason it is difficult to have a definite melting point for the glasses.

And then further it is extremely viscous, highly viscous that viscosity is more than order of 10 power 12 Pascal seconds so that to avoid crystallization. So, basically physically if you wanted to say that it is actually liquid which is rigid and under cooled having no definite melting point and then high viscosity very high viscous liquid that way you can define a glass physically.

Chemically it is a combination of non-volatile inorganic oxides. Alright sooner you are going to see the composition and then ingredients and all those things, almost all of them are oxides. It is a it is a union of a non-volatile inorganic oxides resulting from decomposition and fusion of alkali and alkaline earth components, sand and other glass constituents ending in a product with a small amount, but negligible amount of non-vitreous material in the suspension, mostly it is vitreous.

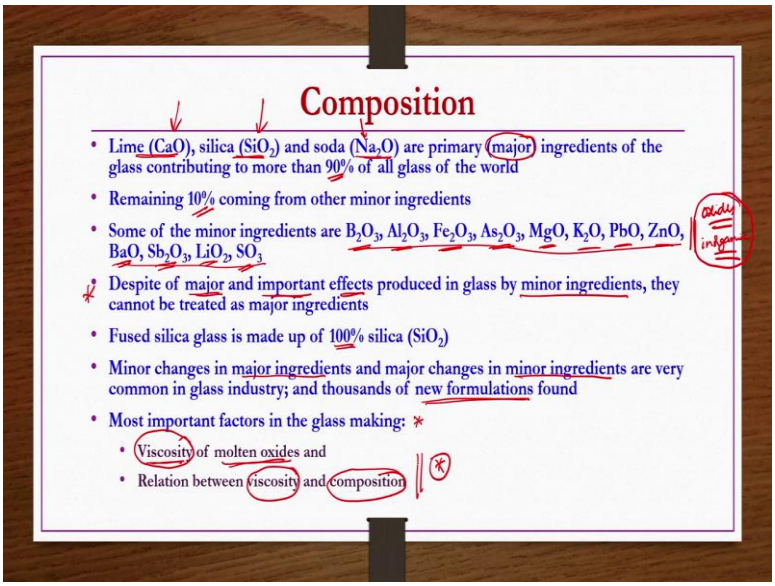
Certain amount of non-vitreous amount is also required in order to provide the strength to the glass alright so but however, it is very negligible, because of its transparency and then its high chemical resistance and then because of effective electrical insulation ability and then ability to contain a vacuum.

It is having several applications and number of applications and then listing all those application is going to be very difficult at one particular level. Some important applications we are going to list under different types of a glasses, commercial glasses.

It is a brittle material which is having very high compressive strength compared to its tensile strength. Recently more strengthening techniques have been developed to the point where glass can be employed in more arduous environments because of that one roughly 800 different glass compositions are being produced.

Some may be emphasizing more on one particular property some may be emphasizing on you know balance amongst different types of properties like that you know different variations are possible. And then based on the variations and changes in the composition approximately 800 different glass components are available in today's market.

(Refer Slide Time: 03:26)



Composition primarily three major constituents of glass are lime that is calcium oxide, silica that is SiO2 and then soda that is Na2O these are the major ingredients, these are the major ingredients of any glass that you take at least two of them would be there.

Only two components are there in sodium silicate type glasses only otherwise all three are there in almost all glasses. That is more than 90 percent of glasses that are produced by the world if you see their contribution. So, these three are there in almost or more than 90 percent of the glasses that are being produced by the world.

Remaining 10 percent coming from other minor ingredients, what are these minor ingredients are boric oxide, alumina, ferric oxide, arsenic trioxide, magnesium oxide, potassium oxide, lead oxide, zinc oxide, barium oxide and then antimony oxide, lithium superoxide, sulfur trioxide. Now, you can see all of them are oxides that is one and then all of them are inorganic. So, at the beginning in the definition we mentioned that say chemically glass is a union of a different types of inorganic oxides, right.

So, these are also major constituents, these are also oxides right and then minor constituents, these are also oxides ok and all of them are inorganic oxides. These inorganic oxides in general bring different types of effects and then these effects are found to be very important major effects in the glass. Despite of that, these minor ingredients are not regarded as major ingredients because of their composition, ok very

small amount they are produced because without these three components like lime, silica and soda, you cannot have a glass, at least two should be there alright.

That is the reason these three are you know taken as a major ingredients right, other ingredients, if you add them there may be some kind of effects, that is the reason they are minor ingredients. Effect may be very important, however, if you do not add them then also you can produce glass right.

But if you do not have any two of these three major components then you cannot make a glass. That is the reason you know these three are considered as a major ingredients of glass despite of the important effects produced by the minor ingredients.

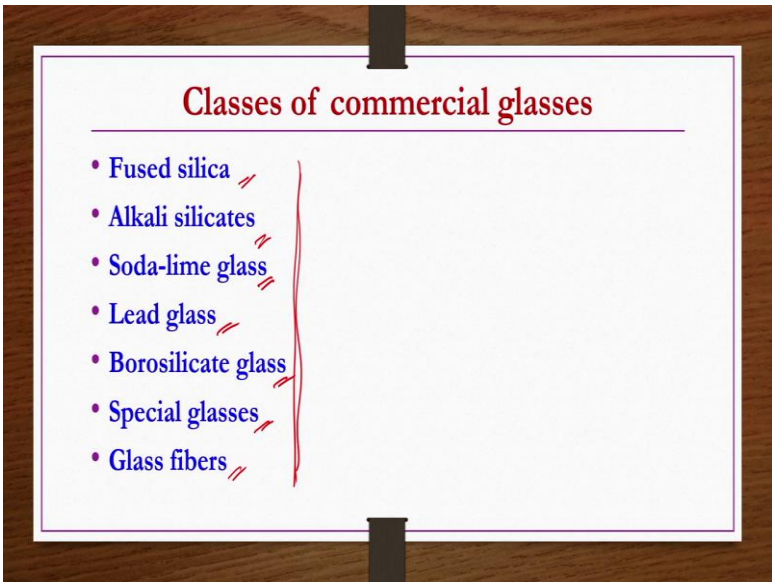
There are a some exceptions like fused silica, it is a completely 100 percent silica glass, alright, but it is silica only, right that is also that is major ingredient ok. So, that is the reason despite of a major and important effect produced in the glass by minor ingredients, they cannot be treated as major ingredients.

Fused silica glass is made up of 100 percent silica, minor changes in major ingredients and then major changes in minor ingredients is very very common in the glass industry and then because of that is one thousands of new formulations are being found.

Most important factors in the glass making is the viscosity of the molten oxides or the molten glass, whatever these oxides when you mix together and then heat it to the high temperature certainly like 1200, 1400 degree centigrade something like that, that those oxides will be molten and then some glass would be form. Of course, there would be some non- vitreous, scum kind of things may also be forming, you remove them and then you get the molten glass.

So, viscosity of that molten glass or the molten oxides is very much important factor and then relation between this viscosity and then composition of the glass that is what are the different percentages of different oxides are being used. So, these two things are very important factors in glass making.

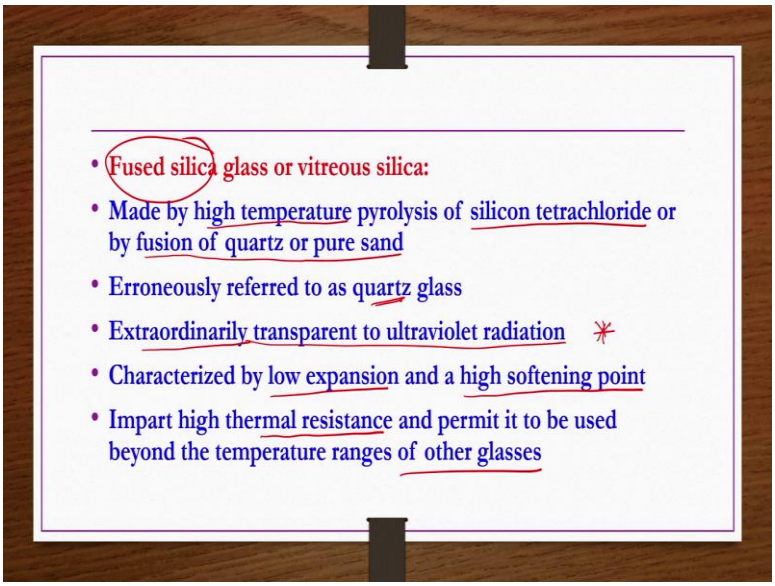
(Refer Slide Time: 07:28)



Now, we see glasses of a few commercial glasses. Fused silica is one glass then alkali silicates another glass which is nothing but sodium silicate glasses then soda-lime glasses more than 90 percent of the glasses that are being available in the world are you know soda lime type glasses.

Then lead glass, then borosilicate glass, special glasses and then glass fibers are a few glasses. These are a few glasses of the commercial glasses available. Now, we cannot see each and every detail of manufacturing of these things and then applications, the engineering problems of each and every of these things. So, then what we do we see a few basic importance of each of these commercial a glasses or group of commercial glasses and then we go into the manufacturing of a flat glass method.

(Refer Slide Time: 08:21)

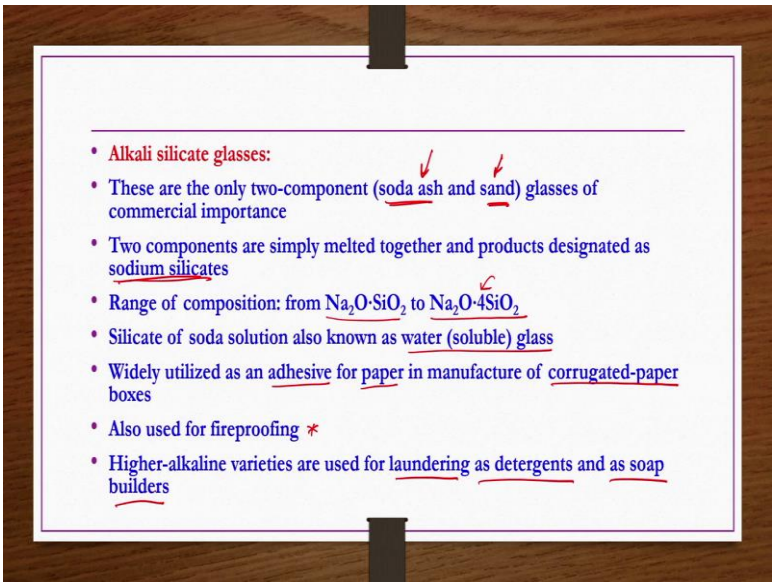


So, let us start with the fused silica glass or vitreous silica. It is made by pyrolysis of a silicon tetra chloride at very high temperature right. If you take silicon tetra chloride and then pyrolyze it in inert atmosphere at very high temperature something around 1200 degree centigrade something like that then you can get this fused silica ok. It can also be produced by fusion of quartz or pure sand.

Sometimes it is also referred as quartz glass, but it is which is not correct. It is having characteristics like extraordinarily transparent to ultraviolet radiations. These kind of special applications are you know characteristics that we are going to discuss for each category anyway rather discussing about the applications uses of each and every glass. It is also characterized by the low expansion and then a high softening point ok.

It imparts high thermal resistance and permit it to be used beyond the temperature ranges of other glasses. Some glasses you can use up to 600 degree centigrade or 500 degree centigrade like that, so this is the one type of glass the fused silica glass where you can go highest possible temperature for operation alright. So, that means, you can use to very high temperature also it is having such high thermal resistance.

(Refer Slide Time: 09:46)

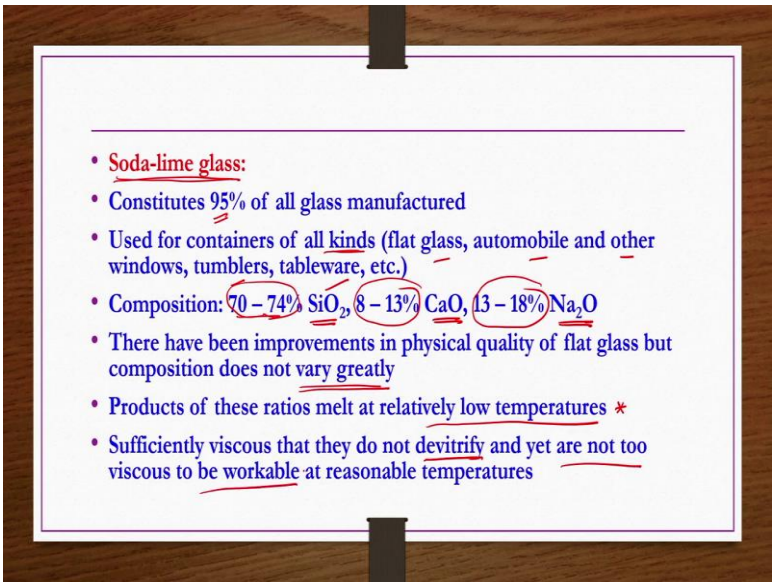


Next one is alkali silicate glasses category. These are the only two component glasses of a commercial importance and those two components are nothing, but soda ash and sand right. Two components are simply melted together and products are designated as sodium silicates, only two components are there soda ash and then sand.

Soda ash you are getting Na2O from soda ash that is soda you are getting from the sand you are getting silica SiO2 right. Only two components are there that is the reason these products whatever are there they are known as the sodium silicates. A range of composition varies from Na2O.SiO2 to Na2O.4SiO2.

Then silicate of soda solution also known as the water soluble glass. These are widely utilized as an adhesive for paper in manufacture of corrugated boxes that is one important application. It is also used for fire proofing purpose. Higher alkaline varieties are used for laundering as detergents and as soap builders for that purpose also these sodium silicates are used.

(Refer Slide Time: 11:01)

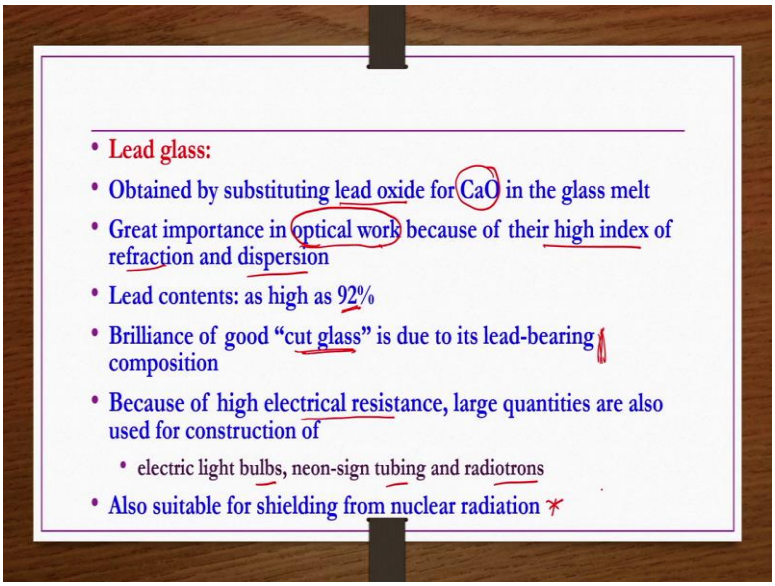


Next one is the soda lime glass category. It constitutes 95 percent of all glass manufactured. More than 95 percent of glasses that has been manufactured by the world if you take and then you check their constituents you can see more than 95 percent of soda lime glasses right. They are used for all kinds of containers like flat glass, automobile, other windows, tumblers, tableware etcetera.

Composition silica 70 to 74 percent lime, 8 to 13 percent and then soda 13 to 18 percents are in general present. There have been improvements in physical quality of flat glass, but does not vary the composition much without varying the composition much. You know Different physical quality flat glasses are being produced under this soda lime category ok, you can see the ranges like silica only varying between 70 to 74 percent only not much.

Similarly, lime is also between 8 to 13 percent only and then soda also 13 to 18 percent only ok. Products of these ratios melt at relatively low temperatures. So, then you cannot use them at high temperature their thermal resistance is less. So, efficiently viscous that they do not de-vitrify ok, but yet are not too viscous to be workable at reasonable temperatures.

(Refer Slide Time: 12:30)

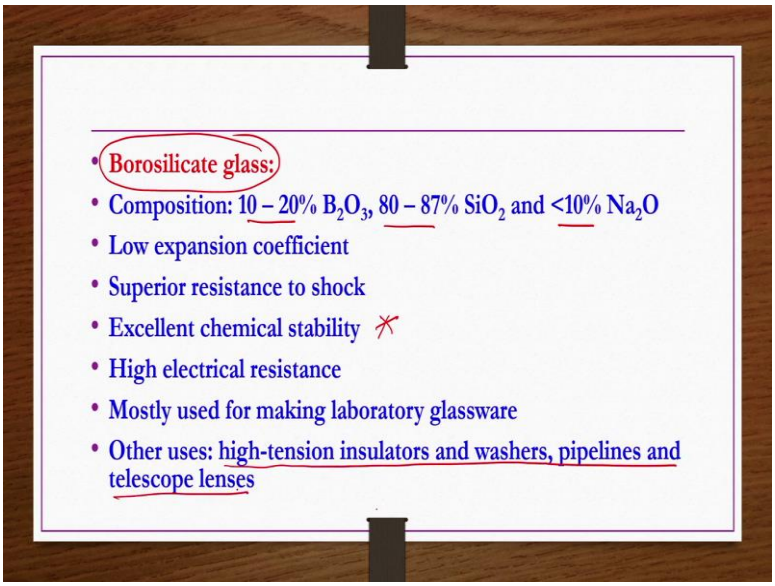


Next category is lead glass category obtained by substituting lead oxide in place of calcium oxide that is lime in the composition of a glasses. You replace the calcium oxide by the lead oxide then whatever the glass that you get that is nothing, but the lead glass known as the lead glass.

Great importance in optical work because of their high index of refraction and then dispersion so, most of the optical glasses are prepared by these lead glasses. Lead content can be as high as 92 percent that much lead is also being there depending on the applications and then sometimes you see cut glasses. So, called the brilliance of those good "cut glasses" is due to it is lead bearing composition ok.

They have a high electrical resistance because of that one large quantities are also used for construction of electric bulbs etcetera, neon, sign tubing and radiotrons etcetera. Also suitable for a shielding from nuclear radiation this is the very important application you can see ok.

(Refer Slide Time: 13:41)

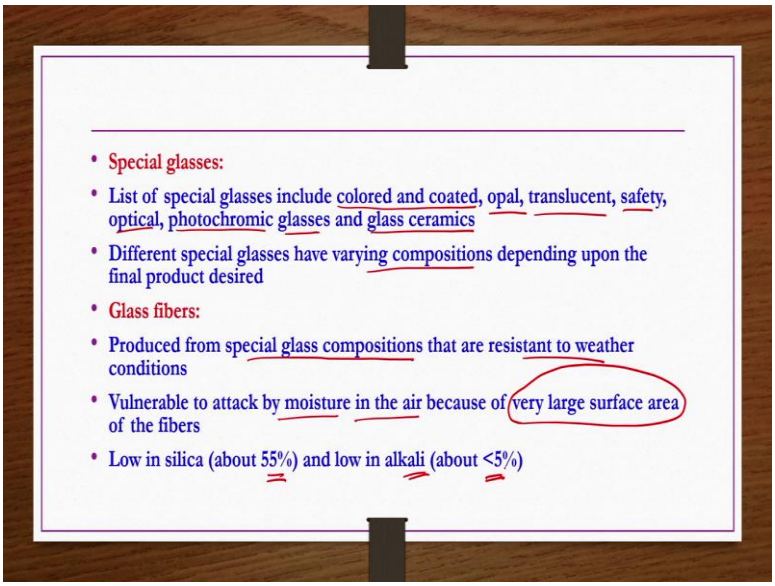


Borosilicate glasses category this type of glasses often you find in laboratories in almost all laboratories whatever the glass vase are used mostly borosilicate type glasses.

Composition: boric oxide 10 to 20 percent, silica 80 to 87 percent and then soda less than 10 percent. It has low expansion coefficient. So, if it is having low expansion coefficient obviously, it is shock resistance is going to be superior or resistant to shock is superior. It is having excellent chemical stability that is the reason mostly in laboratories chemical laboratories this borosilicate glasses are used.

It is having high electrical resistance mostly used for making laboratory glassware other uses are high tension insulators and washers, pipelines and telescope lenses.

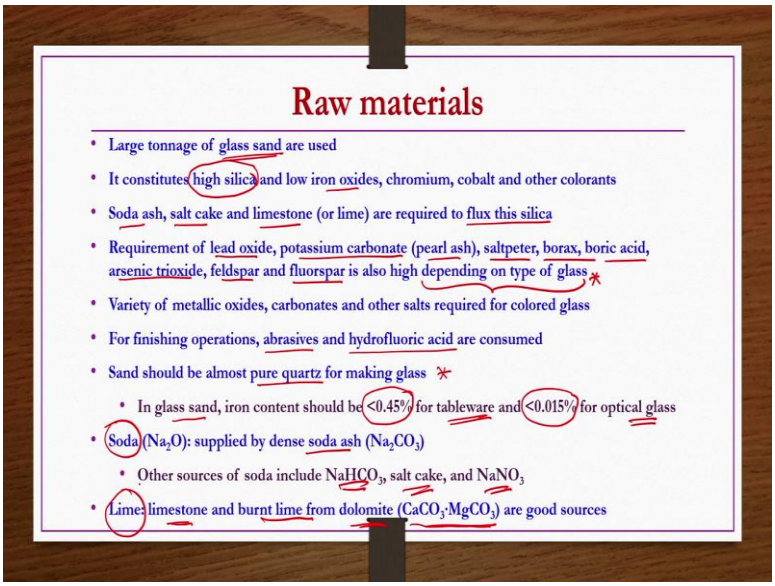
(Refer Slide Time: 14:36)



Special glasses these special glasses include a list that is colored and coated glasses, opal, translucent, safety glasses, optical glasses, photochromic glasses and glass ceramics alright. So, different special glasses have varying composition depending on upon the final product desired right, whether you wanted to have a safety glass or optical glass or glass ceramic depending on that one where a composition would definitely be changing.

Then last category is glass fibers, it is produced from special glass composition that are resistant to weather conditions. These are vulnerable to attack by moisture in the air because of very large surface area of these glass fibers. These are very low in silica about 55 percent and then low in alkali that is about less than 5 percent or even less. So, these are a few basics about the composition applications of different types of commercial glasses or groups of commercial glasses that is what we have seen.

(Refer Slide Time: 15:43)



Now, we see the raw materials. Actually, we have already seen that the lime silica and then soda are the three major important contributors are three major ingredients of the glass right. So, apart from that one there are some minor ingredients are also there. So, all of them are having specified application.

They are not used to just because they are in organic oxides and then glasses are nothing, but molten in organic oxides not because of that reason, simply you cannot add any in organic oxide. They have been selected for different purposes and then different composition of each ingredient is used based on the applications. So, it is important to know what are the reasons for incorporating different types of you know ingredients including the major as well as the minor ingredients right. So, that is what we are going to discuss now.

Large tonnage of glass sand is used because from the glass sand you can get the silica because this glass sand is very rich in silica and then very less amount of iron oxide, chromium, cobalt and other colorants would be there right. So, you need silica so then high silica is there in the glass sand so then usually if you have silica directly it is used otherwise glass sand is often used because it is very rich in silica.

Then soda ash, salt cake and limestone are required to flux this silica in the process and then a requirement of lead oxide, potassium carbonate or pearl ash, saltpeter, borax, boric acid, arsenic trioxide, feldspar, fluorspar is also high depending on type of glasses. So,

these are the minor ingredients right, but they also requirement is very much essential and then how much it is required each of minor ingredients that depends on the application or the type of the glass ok.

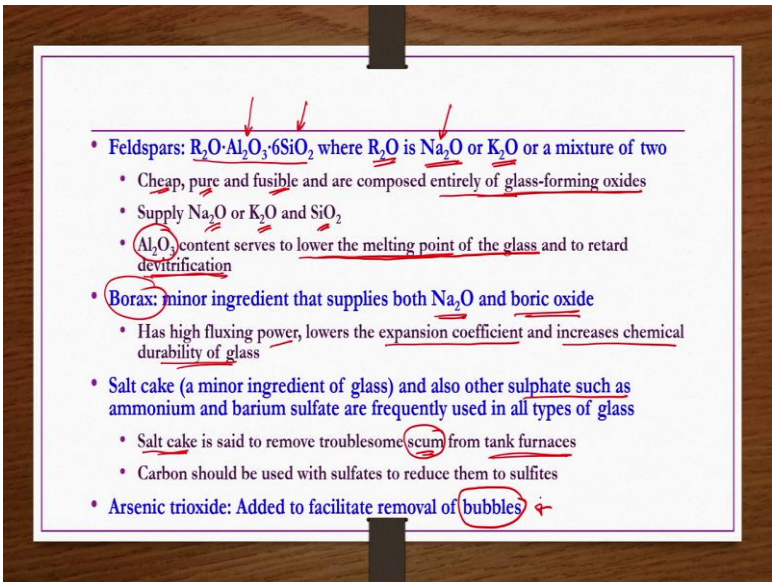
Now, what we see? We see source of these ingredients whether major or minor in addition to that one if any general, chemical formula etcetera. And then you know what is the purpose they have been incorporated as an ingredient in making the glass, that is what we are going to see now.

Variety of metal oxides, carbonates and other salts required for the colored glasses. For finishing operations abrasive and hydrofluoric acids are also consumed, sand should be almost pure quartz for making glass. In glass sand iron content should be less than 0.45 percent for tableware glasses if you are producing and then if you are producing optical glasses there should be even less that is less than 0.015 percent, because this iron content may be providing strength to the glass, but it decreases the vitreous nature or it makes the glass de-vitrified if you have the higher contents of iron.

Soda it is supplied by the dense soda ash, other sources of the soda are sodium bicarbonate, salt cake and then sodium nitrate. Coming to the lime, lime stone and then burnt lime from the dolomite that is nothing, but $CaCO_3$, $MgCO_3$ are good sources for the lime. So, lime, soda and then silica that we have already seen ok.

So, now we talk about the minor ingredients.

(Refer Slide Time: 19:16)



Feldspars is one important minor ingredient which is having chemical formula R2O, Al2O3, 6SiO2, where R2O can be Na2O or K2O are a mixture of these two right. It is cheap, pure, fusible and are composed entirely of glass forming oxides. You need silica, right, you need soda, you know both of them are there. Alumina also sometimes you need in order to lower the process temperature right Alumina is also required.

So, you know you can see this is one of the important component which is having composed of entirely glass forming oxides. So, that is the reason it is minor ingredient, but important one because it is a source of a Na2O, K2O, SiO2, Al2O3 right. Supplies Na2O or K2O and then silica as well, Al2O3 contents are to lower the melting point of the glass and to retard devitrification.

If the glass is not vitreous, it will not serve the purpose right. So, devitrification should be avoided, so that can be avoided or reduced by using alumina. Other application of alumina is to lower the melting point of the glass. Borax, it is also a minor ingredient that supplies both soda as well as the boric oxide B2O3.

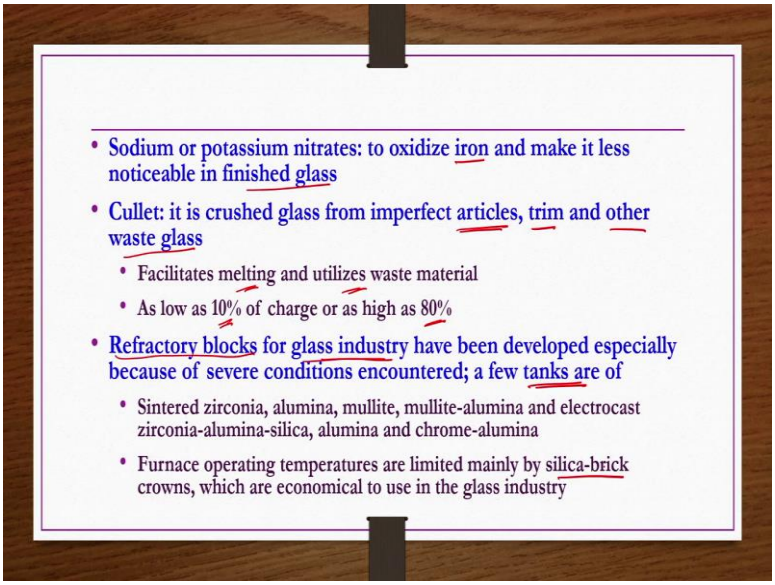
It has the high fluxing power and then lowers the expansion coefficient, expansion coefficient should be very low otherwise you know slightly increase temperature and then break of the glass may take place and then increases chemical durability of glass. This borax is used for these purposes ok.

Salt cake which is also a minor ingredient of glass in addition to that one, other sulfates such as ammonium and barium sulfate are frequently used in all types of glasses because salt cake is said to remove troublesome scum from the tank furnaces. While making molten glass, you know these inorganic oxides are taken in a tank furnace and then heat is supplied. So, then all these will be melting and then forming molten glass.

But you know some impurities would be floating on the surface like scums they should be removed. So, salt cake is useful in removing such kind of scums. Carbon should be used with sulfates to reduce them to sulfites. And then arsenic trioxide is used to facilitate removal of bubbles. Bubble should not be there otherwise they will be showing as a kind of defects in the glass item so you should try to avoid them.

So, one is that you know you allow the molten glass to melt for sufficiently high time so that these bubbles arises to the surface and then released out of the glass or they will be dissolved into the molten glass itself. That is often done, but if you have arsenic trioxide in the ingredients. So, it will facilitate the removal of the bubbles ok.

(Refer Slide Time: 22:36)



Sodium or potassium nitrates these are used to oxidize iron and make it less noticeable in finished glasses. If iron content is more so devitrification may take place. So, then it should be as less as possible right. So, that can be done by oxidizing the iron using sodium and then potassium nitrates.

Cullet us which is nothing, but a mixture of crushed glasses from imperfect articles, trim and other waste glasses. These are very essential right. They facilitates melting and utilizes waste material because glass is a kind of very sensitive item. So, getting them in a perfect shape, size and then with perfect properties is very difficult sometimes and then whatever imperfect materials are there you can reuse them.

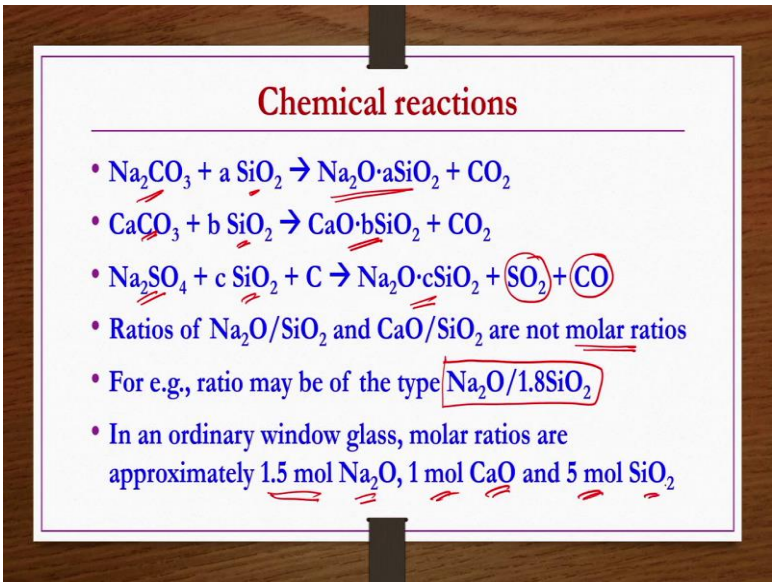
When you reuse them what will happen, the required temperature to melt down the raw materials that will be reduced ok. So, it facilitates the melting of the metal oxides that is forming a molten glass and then utilizes waste material also.

It can be as less as 10 percent or it can be as high as 80 percent of the total charge that is being fed to the tank furnace to make the glass, tank furnaces etcetera are used in order to prepare glasses those things we are going to see them anyway. Pot furnaces and Tank furnaces are two types. Pot furnaces are used for the small quantities something like 1 or 2 tons something like that, whereas the tank furnaces are used for the large quantity glass making like you know hundreds of tons per day something like that.

Then another important thing though it is not ingredient it is very much essential that is refractory blocks for glass industry because you are supplying very high temperature something like 1200, 1400 degree centigrade. So, that these inorganic oxides melt together and then form a molten glass right. So, you need to have equipment that can sustain such kind of high conditions or severe conditions.

So, refractory blocks are essential for that and then few of the tanks or tank furnaces made of the refractory blocks include sintered zirconia, alumina, mullite, mullite-alumina and electrocast zirconia-alumina-silica and alumina and then chrome-alumina these kind of things are there. Furnace operating temperatures are limited mainly by silica-brick crowns, which are economic to use in the glass industry.

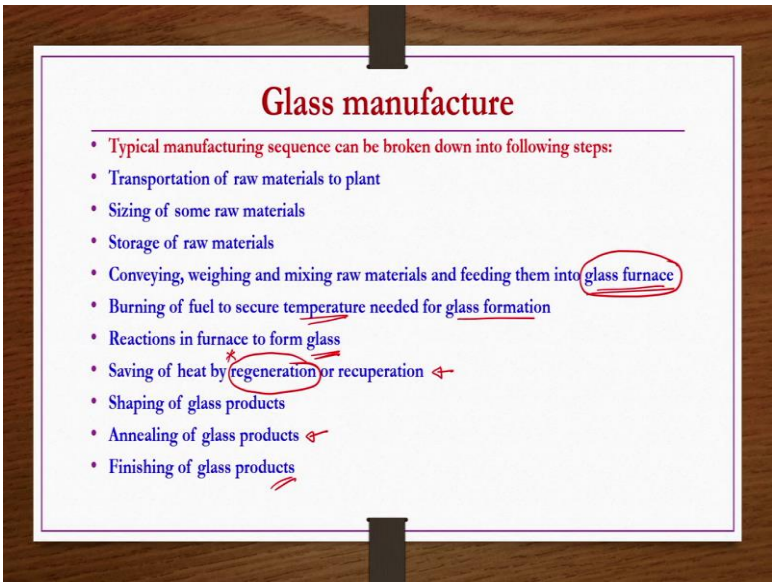
(Refer Slide Time: 25:07)



Now, we see the chemical reactions often occur in the glass making process ok. So, sodium carbonate reacts with silica to give sodium silicates by releasing carbon dioxide and then calcium carbonate reacts with the silica to give calcium silicates by releasing the carbon dioxide whereas, sodium sulfate reacts with the silica to give sodium silicates again by releasing carbon monoxide and then sulphur dioxide right. So, this ABC are not the kind of molar ratios actually right.

So, ratios of Na2O divided by SiO2 and then CaO divided by SiO2 are not molar ratios. These are in general in the form like you know Na2O divided by 1.8 SiO2, these kind of numbers are required if you wanted to present them in molar ratios. In an ordinary window glass, molar ratios are approximately 1.5 moles of soda, 1 mole of lime and then 5 moles of a silica.

(Refer Slide Time: 26:14)



Now, we discuss about glass manufacturing. We list out the steps involved in a commercial glass making process or glass plant right. So, these are transportation of raw materials to plant which may be common to any of the industry not only specific to the glass industry. Then sizing of some raw materials that may also be common to most of the chemical plants. Storage of raw material that may also be very common to majority of the chemical especially inorganic chemical industries.

And then after that conveying weighing and mixing raw materials and feeding them into glass furnace or tank furnace. This one glass furnace or tank furnaces are the furnaces in which these inorganic oxides or you know these inorganic oxides are supplied energy in these furnaces to get the molten glass alright.

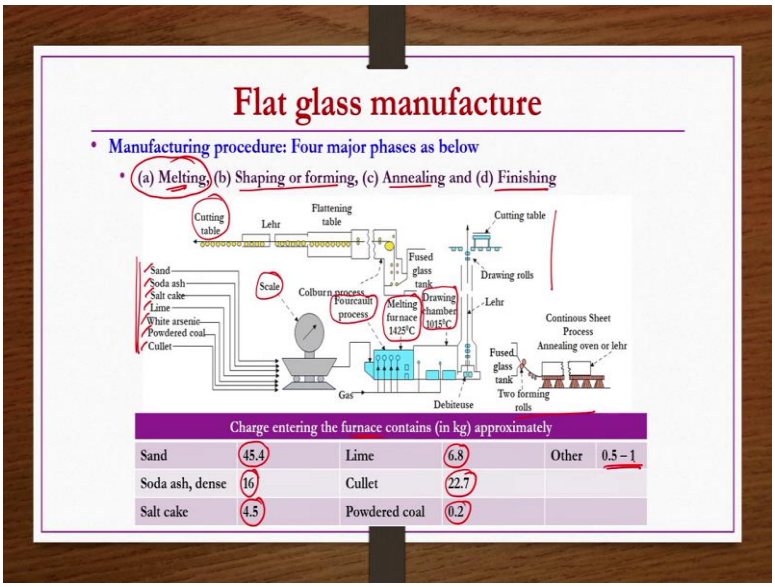
Then burning of fuel to secure temperature needed for the glass formation because we understand melting of these inorganic oxides required high temperature 1200 or something like that. So, then that high temperature should be supplied that ok can be done by burning of fuels. Reactions in furnace to form glasses ok that is another step, saving of heat regeneration or recuperation because when you have such high energy consumed process. So, then you should make sure that how to save the energy alright.

So, regeneration or recuperation are two important processes where lot of energy is being saved ok. So, we are going to discuss about this regeneration process anyway in coming slides. Then shaping of glass products ok this is very much essential depending on the

shape of the final product that you have required. Then annealing of a glass products glass should able to sustain certain level of the stress right. So, that process is done by annealing of glass products right.

So, annealing is nothing, but it is in an oven a properly designed small chamber heat oven in which this annealing is taking place ok, how that we are going to discuss anyway. Finishing of glass products is also requirement because of the final requirements of the product specifications. Now, we have listed here all of this process now what we do, we group them.

(Refer Slide Time: 28:44)



If you group them then we can have a four groups right. So, those four groups we discuss for the flat glass manufacture. Manufacturing procedure four major phases as below one is the melting, then after that shaping or forming, then annealing and then finishing right. So, all the operation that are occurring from the beginning of the collection of raw material and then melting them to the final product finishing you know we can group them in four phases.

Pictorially it is shown here in a flowchart manner here. So, whatever the raw materials like sand, soda ash, salt cake, lime, white arsenic, powdered coal, cullets etcetera whatever depending on the applications or depending on the type of glass you are making you know all these raw materials are taken right.

In the flat glasses these are the things are required right. They are then scaled or weight depending on the composition in order to make a glass of 100 kgs how much of each of this component is required that engineering calculations mass balance one has to do and then accordingly those much quantities has to be weighed and then they will be taken to a melting furnace which is approximately at 1425 degree centigrades right.

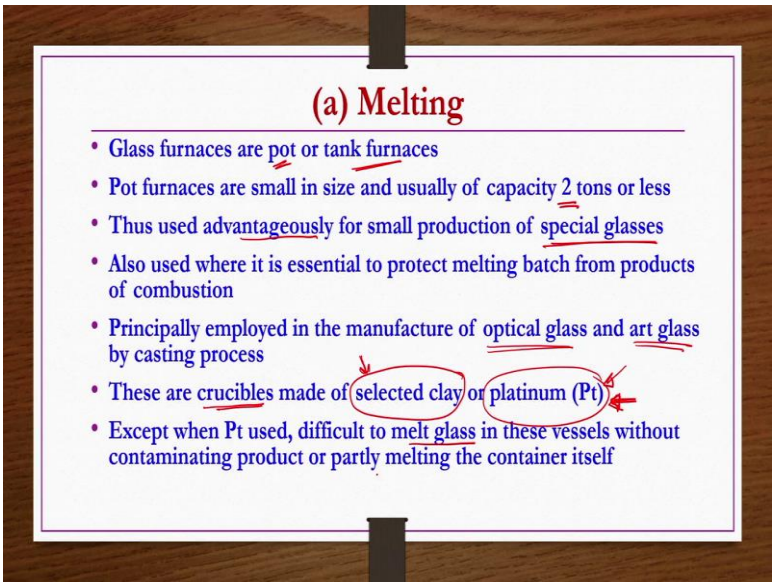
Here fuel and then gases preheated the air etcetera are being supplied. So, that in a required combustion of this fuel takes place and then the energy released by the combustion would be utilized by the ingredients, so that you know melting of these ingredients takes place and then molten glass forms. So, this is known as the fourcault process right. So, here the molten gas whatever is there. So, that is further taken to a drawing chamber which is at slightly lower temperature at a 1015 degree centigrade.

So, here in melting furnace whatever this comes etcetera are formed right. So, they have been removed and after that it is taken to a chamber it is slightly lower temperature like 1015 degree centigrade. From here depending on the you know requirement what type of tables you know glasses you are making and then different processes are there. So, flat glass are you know continuous sheet kind of thing process are there. So, the different processes it may take place.

So, where you do the remaining three steps remaining three steps of shaping or forming annealing and then finishing of the products takes place in these three different ways anyway ok. So, now we are going to discuss about individual steps of glass a making we start with melting then we discuss about the shaping or forming then we will discuss about annealing finally, we conclude the class by discussing the finishing process of glass making.

So, for the flat a glass manufacture charge entering the furnace glass furnace or tank furnace approximately having this one sand you need 45.4 kgs, soda ash that is dense soda ash 16 kgs, salt cake 4.5 kgs, lime 6.8 kgs, cullet 22.7 kgs, powdered coal 0.2 kgs and others ingredients anything you know 0.5 to 1 kgs.

(Refer Slide Time: 31:58)



Now, we start with the melting ok, as I already mentioned melting is done in two different types of furnaces especially for the glass making you know process one is the pot furnace, another one is the tank furnace.

Glass furnaces are pot or tank furnaces, first we start with the pot furnaces because they are small in quantities may be in a crude words you can say that it is something like a crucible that we use in lab, only that in the lab crucibles are very small size in the industries this crucibles are slightly bigger size. So, that you can produce 1 ton of a glass or 2 ton of molten glass per day something like that not more than that one ok.

Pot furnaces are small in size and then usually capacity having 2 tons or less, they are advantageously used for small production of special glasses right, special glasses are not produced in thousands of tons per day in general. So, then it is better to use this kind of furnaces because if you have furnace size increasing the capacity increasing.

So, then energy because you have to supply the energy whether it is pot furnace or tank furnace. So, you know for the small requirements you are using bigger furnace and then supplying more energy. So, then it is not going to be economically feasible.

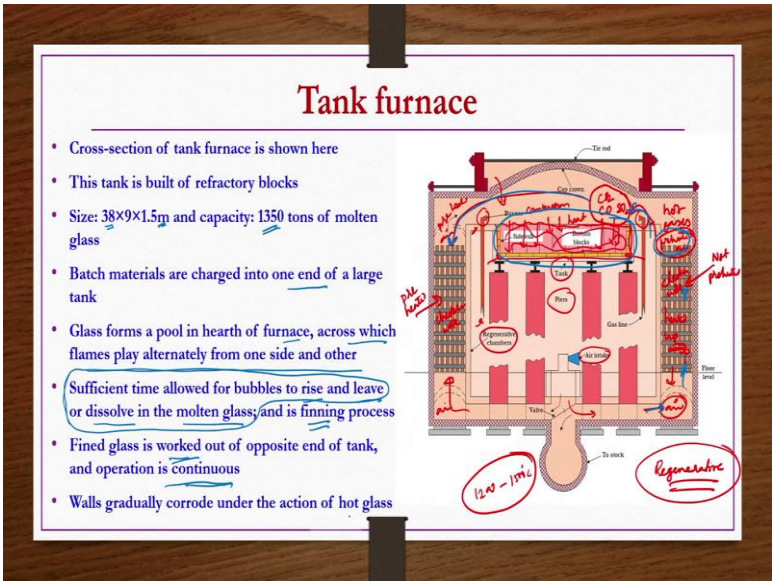
Also used where it is essential to protect melting batch from products of combustion because we understand that you know fuel reacts with the preheated air to combust and then to release the energy. So, then combustion gases may be there. So, then if you

wanted to protect melting batch or the molten batch whatever is there from the products of combustion then also it is very better to use pot furnaces.

Principally it is employed in manufacture of optical glass and art glass by casting process. These are simply crucibles made of selected clay or platinum, obviously when you are taking clay so then they may not be having very high thermal resistance. So, then let us say you are operating at 1400 degree centigrades and then using crucibles made of some kind of clay. So, then obviously, part of the clay may also be melting and then it may be contaminating the product also, but that may not be the case if you are using crucible made up of platinum ok.

So, but it is very expensive so, then crucible should be made of platinum for the production of very expensive glasses, very special kind of glasses except when platinum used difficult to melt glass in these vessels without contaminating the product or partly melting the container itself.

(Refer Slide Time: 34:40)



Now, we talk about tank furnaces. So, cross section of this tank furnace is provided here. So, this is the tank actually this yellow dotted lines whatever this section is shown this is nothing, but the tank in which melting of different types of inorganic oxide is taking place right.

So, this tank is made up of refractory blocks sidewalls and then bottom blocks, these blocks kind of things we can see they are made up of refractory blocks and then this is supported by the different types of piers right. So, feed is coming to this tank from one side let us say coming from this side ok. Then the feed has to be melted. So, you have to supply the energy, how are you going to supply the energy, you have the burners and gas lines different numbers may be there and both the sides would be there right.

So, to this burner the gas lines are fuel lines are you know connected and then fuels are being supplied to the burners. Now you need air at higher temperature right, so that the combustion of these fuel gases by this user burners should be taking place. For that what you do, whatever the air is there that air intake is here that you take right and then pass through a regenerative chamber or this is also known as the checker work chambers right.

So, this is actually initially preheated it is preheated when this air comes and then passes through that air will be preheated by the time it goes out of the this chambers right. So, now, this preheated air would be reacting with the fuel that is coming out through this gas line and then by using the burners the combustion takes place. So, the heat whatever is there that heat would be utilized by the ingredients that are present in the tanks and then they will be melting right.

So, now what happens, when the combustion taking place some combustion gases would also form right, in the reactions we have seen you know CO_2 is forming CO is forming and then SO_2 is also forming some kind of combustion gases right. So, they may also be carrying some energy. In fact, they will also be carrying some energy because they are coming out or evolved because of the combustion of the fuel you know using the preheated air.

So, these hot combustion gases would be passed through other end of the tank right. So, this is one end you know the charge is coming, from the other end these gases are passing and then through other chamber or checker work chambers whatever are there it will be passing through this one. So, this is not preheated right. So, this is preheated actually whereas, this is not preheated.

Now, these hot gases when they pass through this chamber, they will be heated up it will be heated up this chamber would be heated up ok. So, now, these gases will be

circulating like this again this air is this process continues right. Now, here the combustion is done only at one port let us say this is initial port or inlet port this is exhaust outlet port. So, initially for 15 to 30 minutes or 20 to 30 minutes only this port is operative to undergo or to make sure the combustion is taking place well, this is not right after 15 to 30 minutes you know cycle is reversed, cycle is reversed.

So, that the air wall this is operate such a way that now it will be closed, this way it will be closed and then this way air will be going. Now, this air is not preheated obviously, but now what happens, this chamber earlier initially it was not heated, but when this hot gases were passing through this chamber or checker work section this chamber is also heated up.

Now, this air when it passes through here then this air would be preheated and that preheated air would be utilized by the fuel gas and then by making use of burners in combustion of those gases the fuel gases would be taking place. And then energy would be released that energy would be consumed by the inorganic that are present in the tank and then gases you know combustion gases like this CO_2, CO and then SO_2 would be going in the other direction.

Now, it is not heated it is not preheated, but obviously, it is at certain high temperature. Now, because of this reversal of air as well as the fuel line after every 15 to 30 minutes you know lot of energy is being saved let us say when the air is passing through if it is initial stage. Then it has to be preheated this second you know checker work should be right hand set checker work should be preheated, but now in the second cycle it is already heated because of the combustion gases of the combustion process taking place in the first or the previous cycle.

So, that way you can save lot of energy. So, then this is the reason it is known as the regenerative process ok. So, this is what happening here and then once the sufficient you know molt once the liquefaction or once the inorganic oxides are molten and then molten glass has formed. So, there would be some kind of scum sets of formation there will be removed and then this product would be taken from the other side ok.

So, this is a cross section view. So, that is the reason it is looking like that. So, you know basically the purpose is to explain what does mean by regenerative process here, how it is saving the energy, now it is clear it is definitely saving lot of energy. Energy saving is

going to be very effective in glass making process because you may be heating the inorganic oxides to high temperature like 1200 to 1500 degree centigrade depending on the nature of the glass and then composition that is used for making a different types of glasses ok.

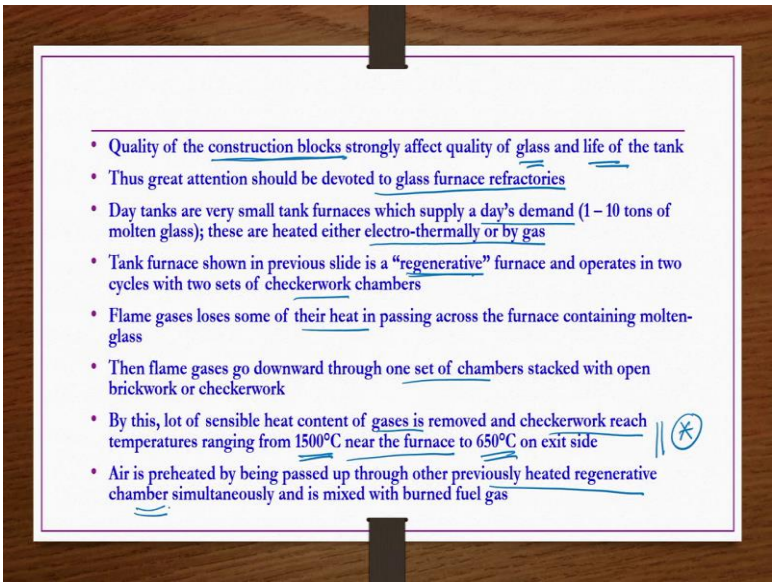
Now, in the same process you know how are we melting the inorganic oxides to get the molten glass that in if tank furnace is being discussed in the form of text here. Cross-section of tank furnace is shown here, this tank is built of refractive blocks the yellow lines whatever shown here and then this is only tank, do not assume this entire thing is a tank, only this part is tank, may be different colors now I use so that you know it will be clear. So, this part is only tank alright.

And then reversal direction may be you know I can give the blue line so that you can understand clearly ok. So, these refractory blocks are made up of you know different types of refractory items you know that we have seen in the previous slide size they may be having 38 by 9 by 1.5 meters and then capacity it can be having high capacity like 1350 tons of molten glass can be hold at a time.

Batch materials are charged into one side of a large tank, glass forms a pool in hearth of furnace, across which flames play alternatively from one side another, from actually this operation first we are you know operating from left to right or in a clockwise and then after 15 minutes it is operating in a anti-clockwise kind of thing 15 to 30 minutes is a interval time. So, that is how these flames are operating or playing alternatively from one side another.

Sufficient time allowed for the bubbles to rise and then leave or dissolve in the molten glass and this process making bubbles to go out of the molten glass or dissolve into the molten glass is known as finning process. So, fined the glass is worked out of opposite end of the tank and operation is continuous. Walls gradually corrode under the action of hot gas. So, that is one engineering problem one should careful.

(Refer Slide Time: 43:47)



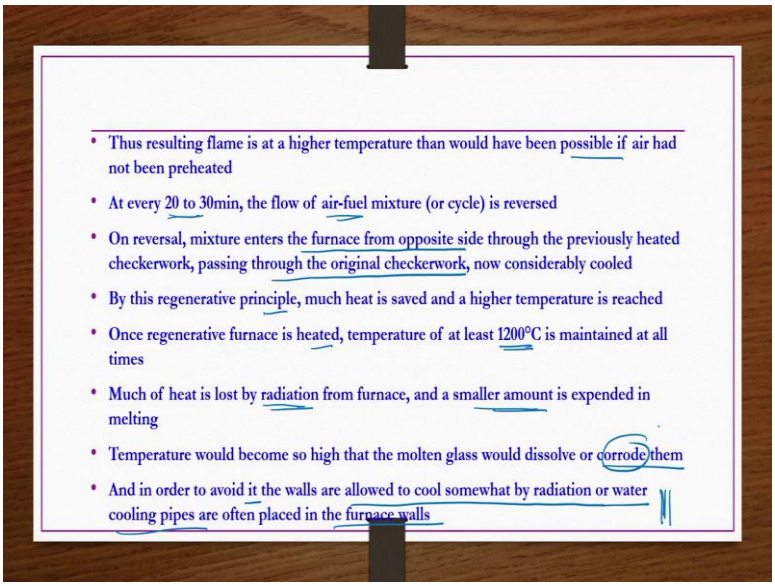
So obviously, quality of glass and then life of the tank depends on the quality of construction blocks. So, it is very important factor. Thus, great attention should be devoted to glass furnace refractories as well, not only just in making the glass, but also glass making you know such a big tank you are constructing and then you are producing continuously glass at high quantities high capacities by supplying high energy.

And then if it is breaking in 6 months or one year there is no point, it should work at least for a few years without any problem then only the plant can be growing progressively especially from the economics point of view. Day tanks are very small tank furnaces which supply a day's demand of 1 to 10 tons of molten glass and these are heated either electro thermally or by gas.

Tank furnace shown in previous slide is a "regenerative" furnace and operates in two cycles with two sets of checker work chambers. Flame gases lose some of their heat in passing across the furnace containing molten glass then flame gases go downward through one set of chambers stacked with open brick work or checker work.

By this, lot of sensible heat content of gases is removed and checker work reaches temperatures ranging from 1500 degree centigrade near the furnace and then lower limit of 650 degree centigrades on the exit side. So, that much is essential important about this regenerative process. Air is preheated by being passed up through other previously heated regenerative chamber simultaneously and mixed with burned fuel gas.

(Refer Slide Time: 45:37)



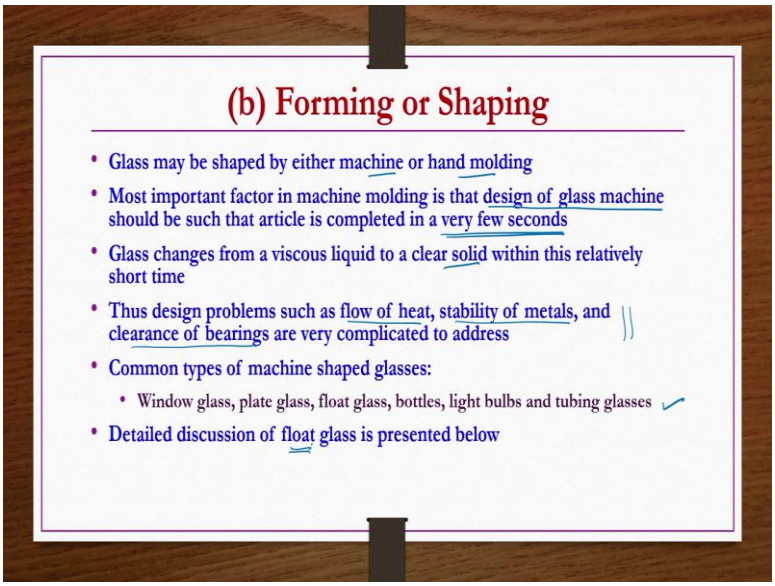
Thus, resulting flame is at higher temperature than would have been possible if air had not been preheated by this regenerative chambers. At every 20 to 30 or 15 to 30 minutes the flow of air fuel mixture or cycle is reversed. On reversal, mixture enters the furnace from opposite side through the previously heated checker work, passing through the original checker work and now considerably cooled.

By this regenerative principle, much heat is saved and the higher temperature is reached. Once regenerative furnace is heated temperature of at least 1200 degree centigrades is maintained at all times. Much of the heat lost by radiation from furnace and a smaller amount is expanded in melting.

This is also you know lost losing the heat by radiation is also sometimes important to avoid the corrugating of the refractive walls. Temperature would become so high that the molten glass would dissolve or corrode them and in order to avoid it the walls are allowed to cool down somewhat by radiation or by water cooling pipes which are placed in the furnace walls ok.

So, if you wanted to avoid the walls to be corroded then you should have either of these two. You either allow heat loss by radiation or supply water cooling pipes in the furnace walls. So, that was all about the melting process which is very essential process of glass making.

(Refer Slide Time: 47:17)

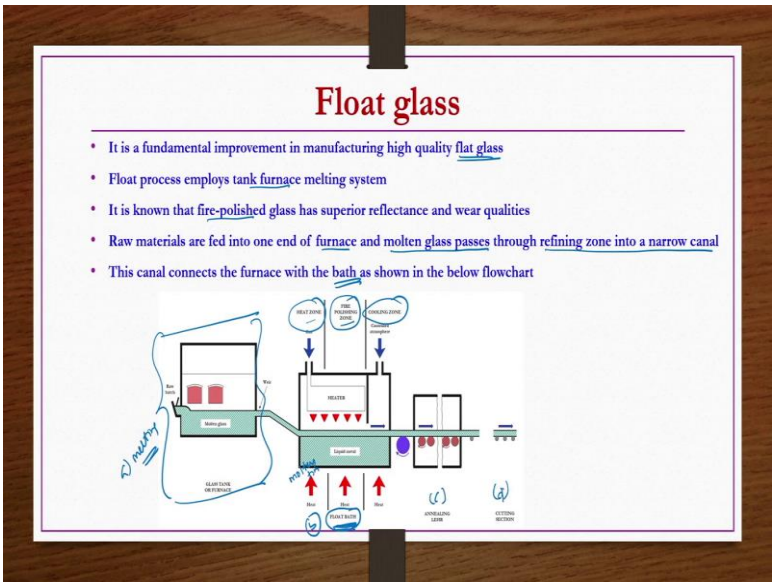


Now, we see the second step of the process that is forming or shaping. Glass may be shaped either by machine or by hand molding. Most important factor in machine molding is that design of glass machine should be such a way that article is completed in a very few seconds.

Because using the molten glass by the time you are giving a shape you know the material become from viscous to solid within fraction of second. So, within that fraction of second required shape should be given so that way machine should be designed ok.

So, glass changes from a viscous liquid to a clear solid within this relatively short time which is very few seconds. Thus, design problems such as flow of heat, stability of metals and clearance of bearings are very complicated to address in machine molding. Common types of machine shaped glasses are window glass, plate glass, float glass, bottles, light bulbs and tubing, glasses etcetera, detailed discussion of float gas is presented below float gas ok.

(Refer Slide Time: 48:19)



It is a fundamental improvement in manufacturing high quality flat glass. Float process employs tank furnace melting system. It is known that five-polished glass has superior reflectance and wear qualities. Raw materials are fed into one end of furnace and molten glass passes through refining zone into a narrow canal as shown in the picture here. This canal connects the furnace with the float bath as shown here. So, this is the melting section right, pictorially it is shown right.

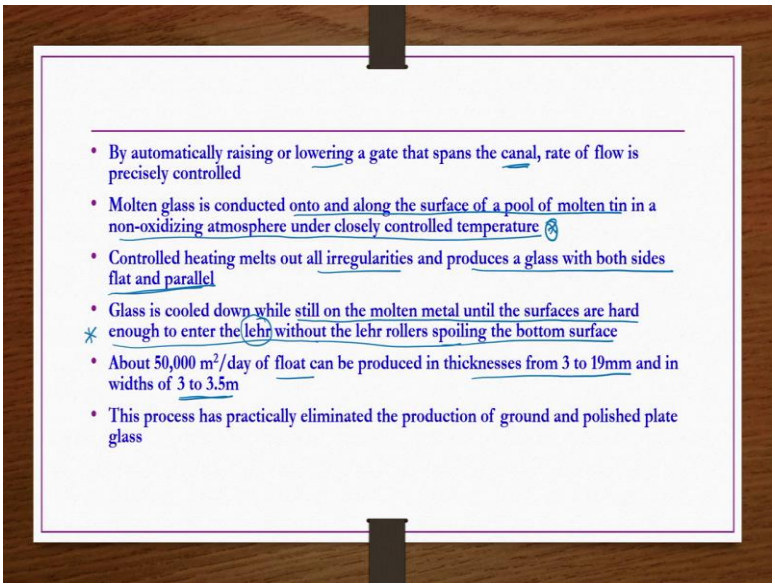
So, the same thing whatever we discussed in until now in the previous you know in a few slides before this. So, this is the melting section. Now, this is the B section where the float bath is there. So, from here molten glass is sent to a float bath through a canal or a wear which is very small cross section. Now, by lifting the opening partly you know you allow the glass to come. So, the opening is precisely maintained ok.

So, now liquid metal has come here and then this is you know undergoing three process under the float bath where there is zone heat zone, there is a fire polishing zone and there is a cooling zone. All three steps are taking place within the float bath. Why we call this float glass produced by this method though we are producing a flat glass, but of high quality because the molten glass whatever is there that is you know sent onto the surface of a molten tin. On to the surface of molten tin this molten glass is allowed to float on and then pass through.

So, because of that one you know what happens not only topside bottom side of the glass is also very fine very clear. That is the reason since it is floating on molten tin this is known as a float glass and then this equipment is known as the float bath. Now, in this float bath the molten glass which is floating on molten tin passes through three different sections heat zone, fire polishing zone and then cooling zone.

When it goes out of the cooling zone it is almost done and then only remaining two steps annealing and then cutting or finishing are only required that we are going to discuss anyway.

(Refer Slide Time: 51:00)



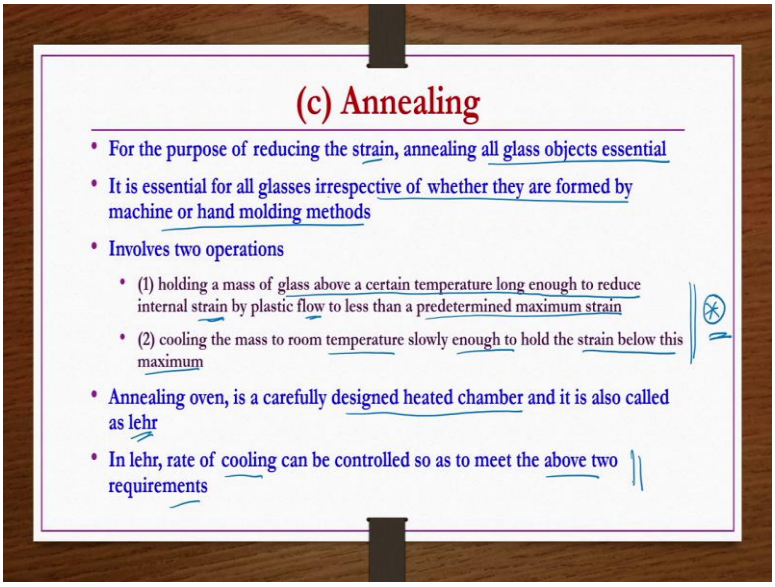
By automatically raising or lowering a gate that spans the canal or wear rate of flow of a molten glass is precisely controlled because you need to send precise amount of a molten glass to the float bath. molten glass is conducted onto and along the surface of a pool of molten tin in a non-oxidizing atmosphere under closely controlled temperature this very much essential.

Controlled heating melts out all irregularities and produces a glass with both sides flat and parallels that is the reason the quality of the flat glass that you produce by float method is very high quality. Glass is cooled down while still on the molten metal until the surfaces are hard enough to enter the lehr without the lehr rollers spoiling the bottom surface.

Lehr is nothing, but annealing oven right which is the next step in that one often you know when you do that process one side of the glass surface is spoiled in general, but that is avoided because of glass is being cooled down within the you know float bath itself.

About 50,000 meter square per day of float can be produced in thickness from 3 to 19 mm and in widths of 3 to 3.5 meters. This process has practically eliminated the production of ground and polished plate glass.

(Refer Slide Time: 52:35)



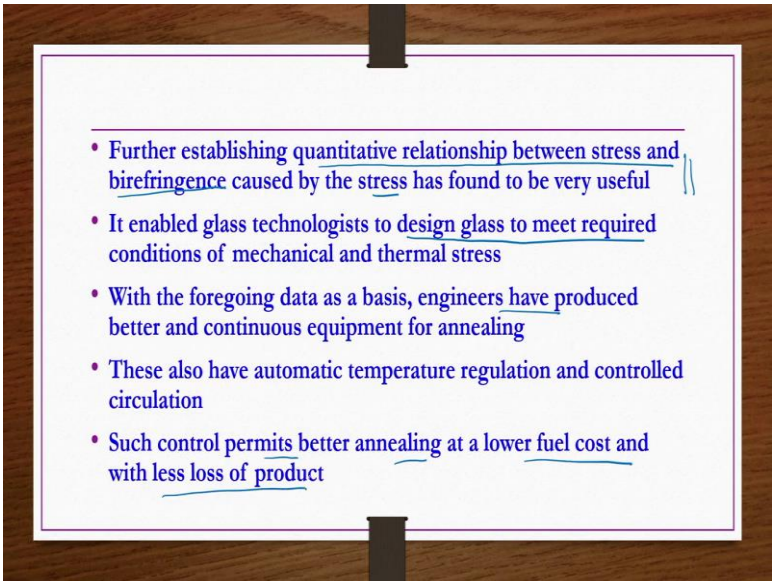
Now, we see annealing process. For the purpose of reducing the strain, annealing all glass objects is essential. How you do? It is essential for all glasses irrespective of whether they are formed by machine or hand molding methods right. Irrespective of that one this annealing should be done.

It involves two operations, holding a mass of glass above a certain temperature long enough to reduce internal strain by plastic flow to less than a predetermined maximum strain right. Then the second section is the or the second step of the process is the cooling at substantially or very very slow a cooling rate so that cooling the mass to room temperature slowly enough to hold the strain below this maximum point.

Once completing this process glass would be having higher susceptibility towards the strains. Annealing oven which is nothing, but carefully designed heated chamber and it is

also called as lehr. In lehr rate of cooling can be controlled so as to meet the above two requirements.

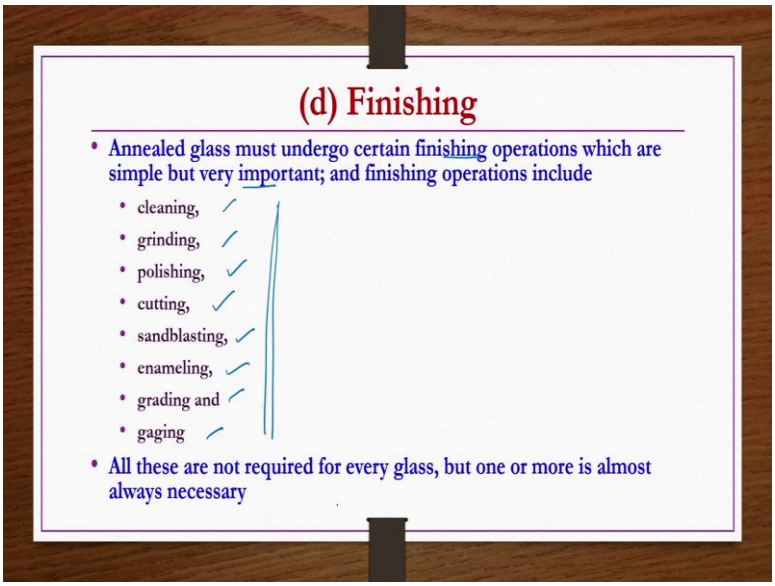
(Refer Slide Time: 53:53)



Since it is a very important process what happened? Developing of quantitative relationship between stress and then birefringence that is refraction in two different direction caused by the stress has found to be very useful from the application point of view. And then it enabled glass technologies to design glass to meet required conditions of mechanical and thermal stress. With the foregoing data as a basis, engineers have produced better and continuous equipment for annealing.

These also have automatic temperature regulation and controlled circulation as well. Such control permits better annealing at a lower fuel cost and with less loss of product. So, that is what about the third step of the glass making that is annealing. Now, the last step of glass making would be discussed that is finishing.

(Refer Slide Time: 54:43)

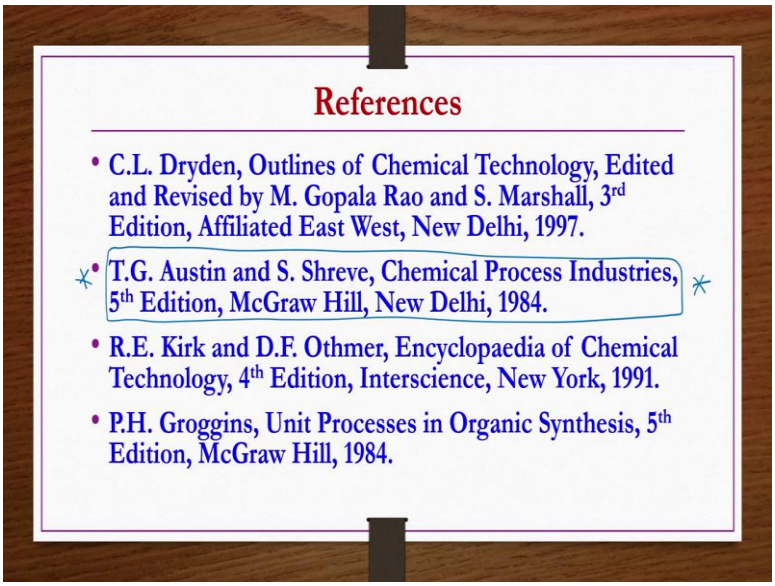


Finishing is very much essential right because that is the final state of the product that customer is buying right. So, it is very much essential to have a proper finishing of the product.

Annealed glass must undergo certain finishing operations which are simple, but very important and finishing operations include steps like cleaning, then grinding, then polishing, cutting and then sandblasting, enameling, grading and gaging ok. So, all these steps may not be required for all types of glasses, but each type of glasses may be requiring at least a few of them ok depending on the product etcetera.

Nature of the product, nature of the glasses and then final requirements etcetera definitely some of them are required. So, this is all about the glass industries that we supposed to discuss in the present lecture. Now, the references for this lecture are provided here.

(Refer Slide Time: 55:46)



Most of the details of this lecture can be obtained from this text book or the slides presented here, in today's lecture are prepared by this reference book.

Thank you.