Glass in Buildings: Design and Application
Prof. N. S. Venkatamurugan
Department of Civil Engineering
Indian Institute of Technology, Madras

Lecture - 03
Float Process for Manufacturing Glass

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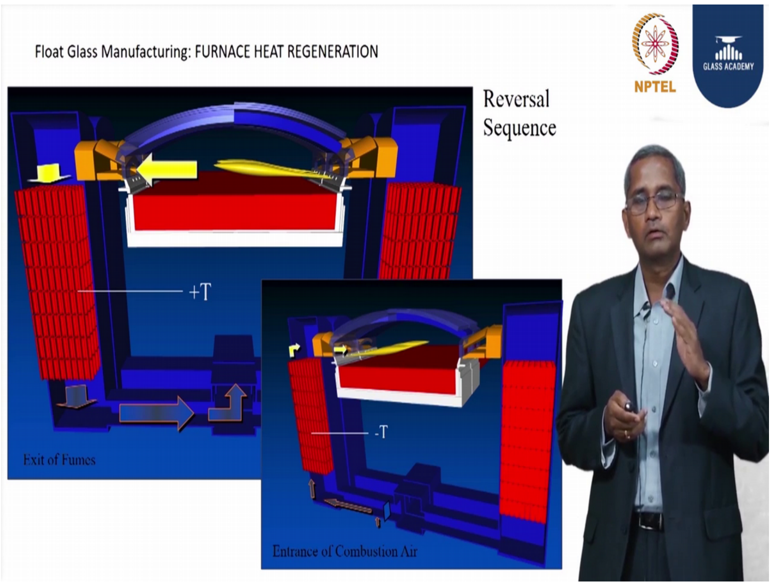

In this process what we do is for 20 minutes of firing continues in the first picture which you see on the background. The firing has been happening from the right hand side towards the left hand side, the flue gas at a high temperature has been going down through the regenerators at 1450; whatever flue gases come in, the heat has been observed stored in the regenerators, and the flue gas is wasted through the chimney at 450 degree centigrade. And this regenerator after 20 minutes is now more or less full with lot of heat. At this particular point of time point we stop the fuel and the combustion air on the right hand side and make the change in the equipment such that the combustion starts from the left hand side; which means a fuel oil and the combustion air are coming in the left hand side. The combustion air passes through the regenerator which is already now soaked with heat.

So, this regenerator waters absorb the heat with a flue gas coming at 1450 takes the atmospheric temperature combustion air, passes it through the regenerator and the combustion air enters inside at 1350 centigrade. So, what we lost at 1450 we have majority regained it back in the form of combustion for air for the next 20 minutes time.

So, this combustion air reacts with fresh fuel coming in to keep the temperature of the furnace 1600 degree centigrade. During this 20 minute period when the firing is from the left side, the flue gas goes on to the right hand side regenerator and the right hand side regenerators starts to get the heat and so every 20 minutes we swap around which is called as a reversal, and the heat is recuperated back into the furnace. So, this type of furnace is called as regenerative furnaces which are quite normal long wall glass manufacturers.

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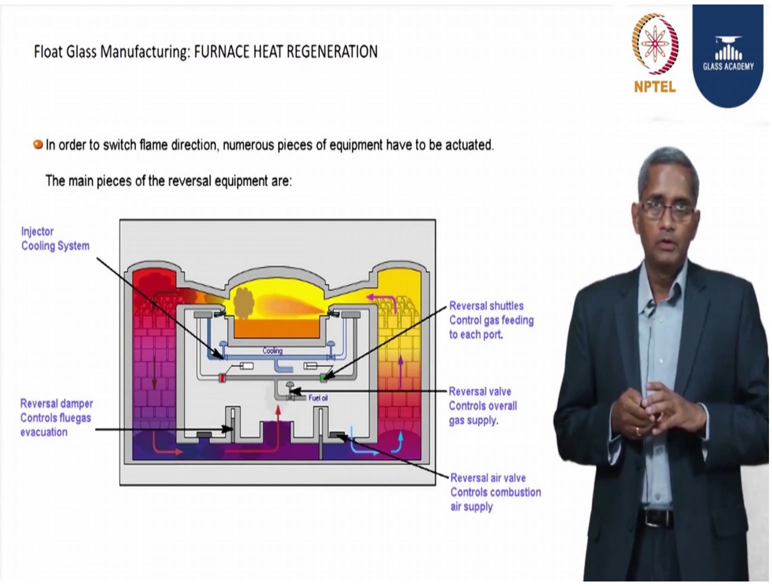

This is another picture to just tell you, another way to clearly understand how the combustion happens. The furnace is the one which is there in the middle; the right two towers the right and left the two towers that you see are the regenerators. In this case the picture as it shows the firing is happening from the right hand side, the flue gas is going to the through the regenerators on the right hand side. And the waste gas is going out the reddish colour on the left hand side regenerator top, and it goes out into the chimney it turns slowly the colour in to blue which means the temperatures have gone down to about 450 degree centigrade.

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So, now having melted the glass to some extent efficiently because we are regenerating the heat, and we have now homogeneously brought the glass together in the neck. And, we have reduced the temperature in the working end to 110 degree centigrade; and this is a very critical temperature 1100. This is the temperature at which we can form the glass; the forming operation like in most of the industries to work on the glass and form the glass to the shape that we want. In this case of the glass manufacturing, we are talking about the dimensions and the thickness the width and the thickness. So, that is formed in the float bath.

The initial introduction I talked about the float bath having molten tin. Why molten tin? And Pilkington brothers invented this particular process in 1957, till then the glass was being made vertically taken up and the glass was trying to follow the gravity and sag. Even though you have good setup rollers on the sides which were taking the glass vertically up the Fourcault and Colburn process since 1913. The optical properties were not as good, because the glass was tending to sag and becoming wavy and so, Pilkington brothers thought: what is the best way to make the glass flat. So, all of us know the flattest of flat surface that we can aim on earth is nothing, but a liquid surface.

So, they thought how about having two immiscible liquids, like oil on top of water if the glass can float on top of something which is molten condition, then we could make the thickness and the width on the glass is floating then that could give a very very flat surface. This idea is what propelled to what we now know as the float glass manufacturing process.

So, they found that it is possible. And for which we need very importantly 3 properties for the medium are rather the substrate on top of which the molten glass can float. One, the glass is at a density of 2.51 kg per liter. And so necessarily the substrate needs to be at a higher density, much higher density than the glass itself so that whatever happens; the glass will always remain on top of the substrate rather than the other way. Tin, as I already said tin is a medium that we use at 7.3 density is very very high in comparison to the glass, so that glass will always float on top of the tin. So, it fulfils a property number one in terms of density, the glass to stay on top of the substrate floating

Second, the good temperature in which the glass can be formed as I said is 1100 centigrade. So, at this temperature the glass has to remain a liquid. And when we can take the glass out of this bath, it can be taken at around 600-610 degree centigrade. This is the temperature in which we can say that the glass is now rigid enough to ravel on rollers. So, at the temperature of 610 also the tin the substrate needs to be in liquid form. So, even at 1100 or 600 we need the substrate to be in liquid form. So, the melting point needs to be in much much lower and the vaporisation temperature need to be much much higher than 1100.

So, the vaporisation temperature of 10 at 230 is much higher than our highest operating temperature 1100 and the melting point of tin at 231 degree centigrade is much much lower than the lowest operating temperature of 610 that we made in at the end of the float bath. So, the tin in addition to 3 other metals which fulfil is chosen because of its availability and the price. And so the tin about 200 to 250 tonnes of tin depending upon the size of the float this poured into the float bath before it is started off. And then the glass when it arrives into the float bath on a continuous basis, it comes at very steady full rate as we call the tons per day the way it is accounted for. It comes and pours the flow of which is control like, how we control the water flow in a dam through a sluice gate, the same way at the end of the furnace there is a tin which is regulated to open more or less to keep a control of the exact quantity of the glass that is designed to flow into the bath. The glass flows in into the bath at 110 degree centigrade and then it pours in and then we need to do some work.

Let us give an let us little bit digress and talk little bit in general. Let us take cooking oil. I pour a small quantity let us say 5 ml in one place a 50 ml in another place. It spreads it spreads differently, but because this oil is same it has got the same viscosity. It spreads and forms a thickness on its own and thickness remains same. Similarly when we pour the glass on to this molten tin it forms a equilibrium thickness of 5.7 millimeter at 1100 degree centigrade with the viscosity of the glass.

If 5.7 is the only size we need we do not have to do any work just pour and take it out and we give it to the customers, but we need to make anywhere between 1.4 millimeter 1.6, 1.8, 2 millimeter, 2.5, 3, 4, 5, 6, 8, 10, 11, 15 and 19 millimeter; glass which is produced on this float bath. So, for different thicknesses we need to make the glass thinner then we need to make the glass stretched and make it thinner. The equilibrium thickness to repeat again is 5.7 millimeter. So, if you want to make a glass thinner than 5.7 we need to stretch the glass and make it thinner if you want a make a glass which is thicker than the equilibrium thickness of 5.7, we need to compress the glass and make it thicker.

And this is done on the bottom right picture as you can see. There are 3 pass off what we call as the top rolls that is shown in the picture, some of the float lines could use as high as 10 top rules depending upon the thickness that we use. This top roll machine has got a cylindrical head which goes inside the bath and gets nipped in into the top of the glass on both edges. This top roll machine can have 4 operating properties: one it is rotating and when it is rotating it is rotating at an anticlockwise direction in such a way that it is pushing the glass forward. The speed at which it can push the glass forward we have a controlled. So, this top roll machine has got a control of speed.

Second, I can push the glass forward at the same time I can make the glass I make I can sorry; I can make the top roll a little bit open up or close. Which means, in addition to moving the glass forward I can also open the angle of the top roll machines such that it is stretching the glass outwards. If I close the angle to a negative angle then I pushed the head of the top roll inner side towards the top roll thereby I am making the glass thicker. So, second property or the parameter we can operate the top roll is the angle on.

In addition to that we need to take the top roll in and out, and also depending upon the width we need to operate at a certain penetration. So, there is an possibility to make the top roll go in or come out. And then how much nip you need to give how much strength you need to give for the glass from the top roll machines, so we need to have a nipping mechanism. So, the top up and down is operated as follow the top roll. So, using this 4 set of properties or the parameters of the top rolls we provide the thickness of the glass.

Now let us understand little bit more I talked about the angle how the speed helps in determining the thickness is. Let us assume for example, the first top roll machine. The speed at which it is pushing the glass I can set it at let us say 2 metres per minute. So, what is the glass coming? Glass is coming at a constant flow rate and is going 2 metres per minute. So whatever is the glass coming the glass is coming at a constant flow rate and its moving 2 meters in 1 minute duration. The next top roll, I increase the speed to 3 meters per minute. Same quantity of glass which has been travel travelling at speed of 2 meters per minute. Now the second machine is forcing it to travel faster at a speed of 3 meters per minute. So, it covers a larger area and natural thickness reduces.

And then the top roll for example, I further increases the speed to 5 metres per minute. So, what is come in 2 and then meters it is become 3 meters now its 5 metres. So, it is going to reduce in thickness much more. So, when I have to make thicknesses which is too small for example, 2 or 1.8 or 1.6 millimeter, we need to employ more number of top rolls to keep on incrementally increasing the speed and stretch in the glass more and as well given a big incremental difference between the one top roll to the next top rolls so that we get the thickness to the lower side.

On the other side, if I have to make the glass thicker I have to compress glass and make it thicker. The first top roll same quantity of glass is coming, I keep the top roll speed at 10 meters per minute, and then the glass is travelling at 10 metres. And second top roll I reduce the speed to let say about 8 meters per minute. So, glass has been travelling fast suddenly you put a break and all of it to go slowly at 8 meters is thickness build up that you can see.

The next top roll I reduce it to 6 meters per minute. Further thickness builds up and progressively if I want to make extreme thickness like 15 millimeter or 19 millimeter, then we keep on employing more number of top roll machines and have a big difference between the speed in the from the one top roll to the next top roll by way of which we could provide the different thicknesses that we want.

So, just to summarise: the float bath is the place where the float glass manufacturing the name comes from. Glass is floating on a molten tin bath; the flattest of flat surface that anyone can aim on the earth is the liquid surface. So, glass floating on a molten tin provides a very flat medium when we make form the glass. And since the glass is formed when we have the flattest substrate the glass that we produce in this method provides the best optical quality that. So, far the manufacturing processes have given us and how the thicknesses has given.

We spoke about the top roll machines which predominantly decide how the thicknesses are formed. Out of the 4 parameters the penetration, the nipping, the angle and the speed. The speed and the angle contribute significantly to the thickness that we want to manufacture. And when we have to make a glass thinner than the equilibrium thickness that is from 2 to 5 millimeter for example, we need to increase the speed and open the angles. And if you have to make the glass thicker we need to decrementally reduce the speed starting with a high value in the first top roll, all the way down to a lower value on the speed and close the top roll angles which will give us the thicker glass. So, this is the float bath process.

And further once the thickness are given the glasses allow to cool down. A few areal coolers which are put in the downstream of the top rolls in order to help the glass reduces temperature to about 610 degree centigrade. At this temperature the glass is taken on the rollers.

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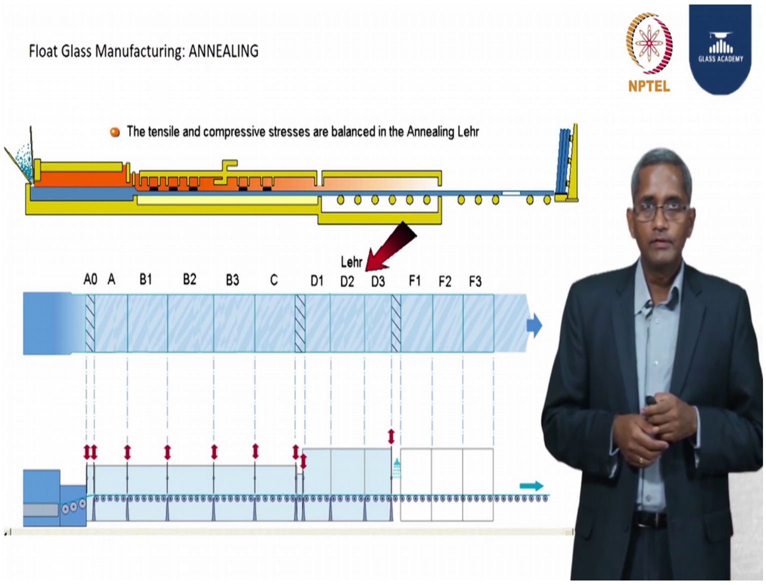

When the glass exits the float bath, now we it passes into the Annealing Lehr. The annealing Lehr as you can see, there is various segments that are given, and in each of the segments the method in which we cool is different. In some of the segments for example, in the A zone the way the air is provided is a cold air, it is an coherent form we can cool the glass very fast. The B segment is divided in to B1 B2 B3, a very long range we have a reason for that I am going to explain that in a few seconds. And after that it is a C zone in which again a cold air mass quantity of glass, air is being passed to have a very little bit of fast rate of cooling. And in the D zone it is a preheated air, but direct and cooling with passing of the air in contact with the glass not through the ducks as it is done in A B and C zones. And in F zones it is done with a mass air cold air directly into the glass to cool at a faster rate.

Now, let us little bit talk about what is this annealing range of the glass. The glass that we make as you saw in the raw materials is using silica, soda, as well as the calcium magnesium etcetera. So, the type of glass that we make comes under the category called as the soda lime silica glass. The soda lime silica glass the annealing range is the temperature range of 480 to 540 degree centigrade which means above the above the temperature of 540 degree centigrade the glass is said to be plastic instead; which means whatever you try to do to the glass (Refer Time: 17:33) pocket whatever it does not take any stress, because the glass is plastic it gets back to its original shape.

Below a temperature of 480 the glass is said to be elastic in its state which means you cannot induce any stress on to the glass permanently, but you can break it. But this temperature range of 480 to 540 for a soda lime silica glass is a annealing range in which whatever stress happens remains permanently in the glass. And this 540 to 480 temperature is actually cold in the B zones. That is why you have a very very longish D zone divided into, in some cases it could even go bigger furnaces these days with 1010 capacity for example, have B1 B2 B3 and B 4. So, we have a very very slow rate of cooling in the B zones.

Why we need to have slow rate of cooling? For example, the rate of cooling if it is uniform you will not have any stress; the stress will remain neutral, but the glass is travelling on a roller; you can cool the top, you can cool the bottom only after the top and the bottom is cooled the center gets cooled. At any point of time the temperature on the surface on the top bottom and the center will always remain different. And the rate of cooling will also be very difference. For the simple reason, we will have stress on the glass, all that what we can do is to reduce the stress closer to neutral.

To give you an simple example what gives us the best stress profile. For example, let us take an example of a balloon. You blow a balloon and you prick it with the pen, it does not form a whole it blast open; why because when the glass there are balloon is blown the forces are acting away from the body tensile stress. So, the moment you initiate a puncture into the balloon, the tensile stress takes this hole and makes it into a rupture. Let us take another example of a car tire. A nail finds it difficult to penetrate into the car tire, but if it penetrates unlike a balloon it does not burst, because the rubber of the car tire is made with compressive stress; the forces are acting towards the body.

So, similarly when we are having high tensile stress when I try to cut the glass, it has a small impact the glass can shatter and break like how a balloon is blasting. When you make a high compressive stress onto the glass you may find it very difficult to cut like in a car tire the nail might find it difficult to penetrate inside. Similarly we might find it difficult to cut the glass. That is why when you do a toughening process we need to pre cut the glass and then you toughed the glass because you cannot cut the toughed glasses.

Like an eraser for example, which is got a mild compressive stress you will be able to slice it with a very clean edge. So, what we are aiming at in the annealing process is to have a good cutting quality and the glass has to come out without any breakage. We better to have a mild compressive stresses on the edges. And this is done with a very slow rate of cooling using a various blowers and different control mechanisms which are inbuilt into the annealing Lehr.

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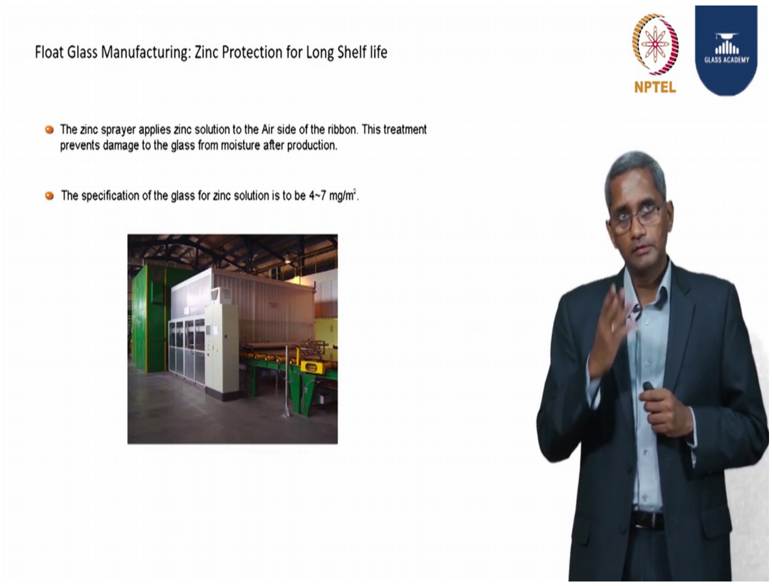

And now the glass is cooled to a temperature of 60 degree centigrade. Now it is time to meet the customers requirement in terms of meeting there dimensions as well as the other quality. For the glass to remind longer in a humid conditions even, to avoid the problem of weathering attack the glass is sprayed with zinc citrate online. So, all the glasses that you buy will have zinc citrate coating protection against weathering which can happen because of a humid atmosphere the glass is stored in the whereas for longer time. So, this is the process that you see on the picture.

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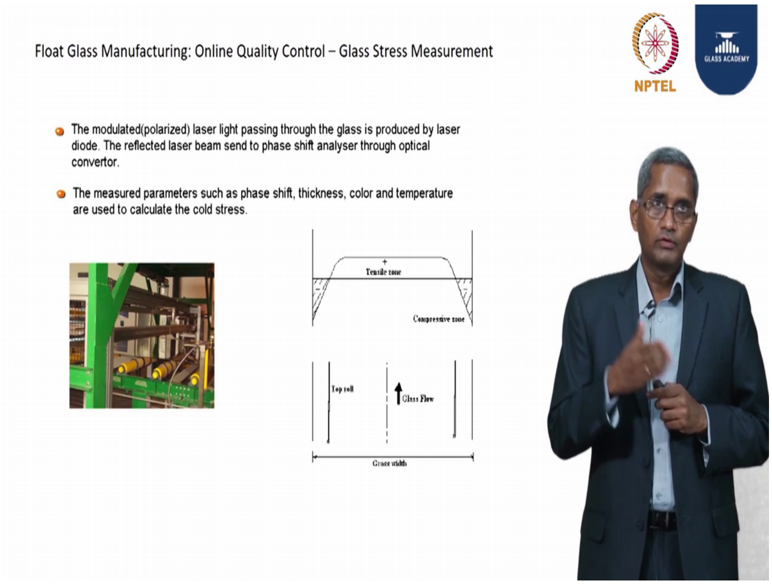

And next is we talked about the stress profile. On the annealing Lehr and there are online equipments which measure and tell us continuously how much is the stress on the glass, so that we can regulate and avoid bad stress glass being sent to the customer.

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Online we also have all the float lines are equipped with a any high tech deduction devices which can spot defects. Un-melted raw materials or bubbles which come because of a pure refining which we talked about the CO 2 that has to escape out of the glass if not done efficiently it can pass into the glass.

Even the defects that we cannot see by naked eye, even with good lighting there are scanners which can tell us where these defects are and these are scrapped online.

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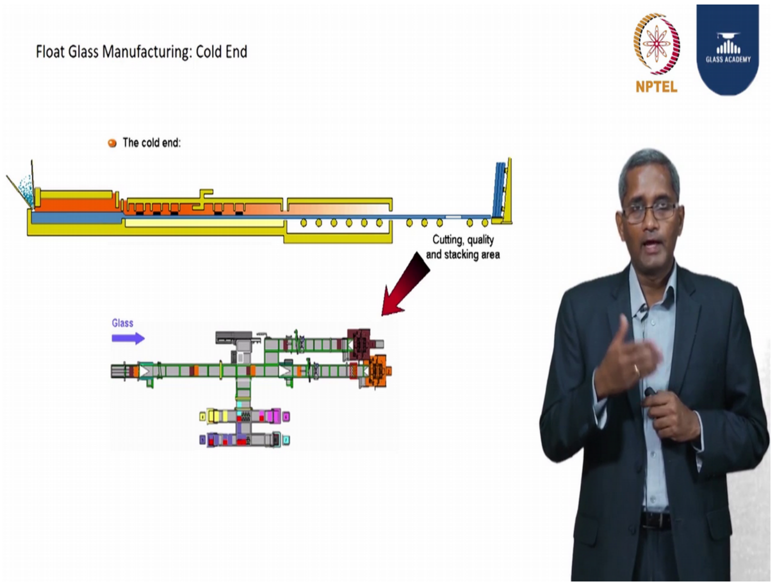

This is a deduction system having deducted and scraped all the bad glasses and how the good glass alone travels into the cutting line. Cutting line depending upon the customers requirement as different possibilities to cut.

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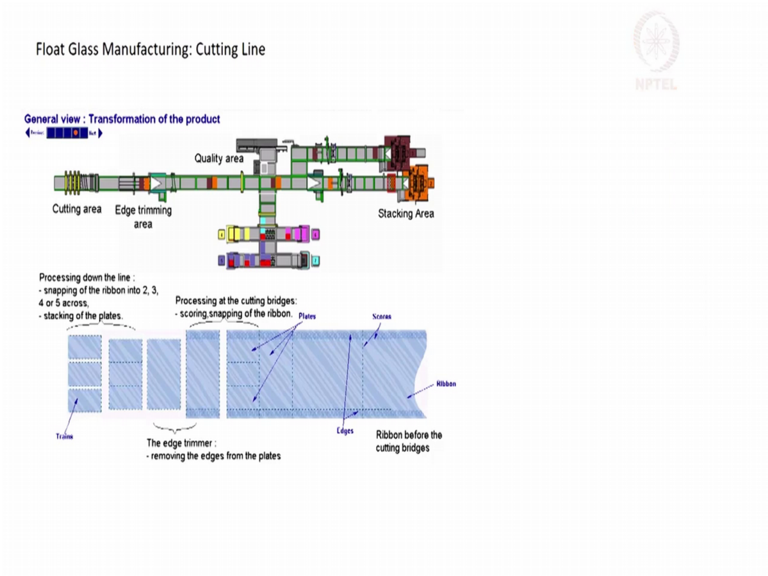

And thus you can see you can cut it into a big size glass called as a jumbo glass or you can cut into medium sized glasses which is called as a DLF or the small standard size is called as a SSS. Take it into the stackers and robots and just to tell you when we think of a glass manufacturing typically in a conventional way we always think that it is a very very high temperature, people are walking very toiling and very dusty atmosphere, but the technology has facilitated these days that all the hot end and the cold end cutting controls as well as furnace operations float bath operations are done through distributed control systems.

There is very minimal people interactions they need to do are minimised the exposure to the heat and dust is absolutely not there. And even when we come down into the cutting line to pick the sheets of a glasses quite like any high technology industry that you would see. There lot of robots and stackers which pick up the glass without any need for in humans to add whole this activity.

So, this is the float glass manufacturing process. And, I hope you got some information related to what you are looking for.

Thanks for watching.

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