Glass Processing Technology
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Lecture- 29
Tempering Part- VI

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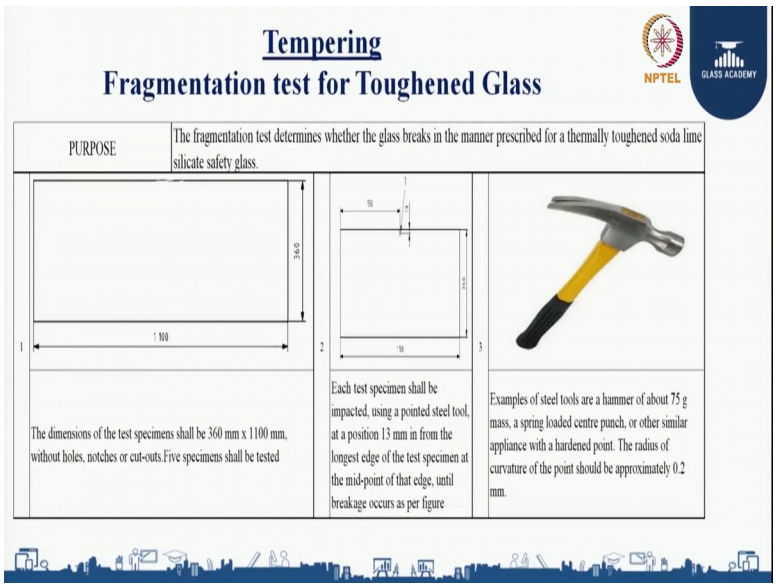

Now, whatever we have discussed this so far, comes under cutting grinding fabrication comes under a pre-process activities. Now let us understand that steps or the tests what we follow under tempering or heat treatment process. During heat treatment process class gains a strength. The physical properties will not change, but there is a increase in the enhancement of the mechanical properties. Now how you are going to determine the mechanical properties or the strength how a glass acquires through tests? One of the test we follow in heat treatment process for a toughened glass is fragmentation test.

So, let us take fragmentation test. The fragment the purpose of fragmentation test is to determine whether the glass breaks in the manner prescribed for the thermally toughened solar soda lime silicate safety glass. Generally, when you see any glass like annealed the raw glass annealed or a HS glass Heat Strengthened glass or a toughened glass. By a visual look you may not be in a position to trace out what is exactly what. Means whether you are selecting annealed glass or whether it is referring to HS glass or it is

referring to toughened. One of the test to identify whether it is a HS glass annealed glass or a toughened glass is a fragmentation test.

So, with the help of breaking the breakage you are going to with the help of breakage pattern, you are going to determine whether it is a annealed glass or a HS glass or a toughened glass.

Now, let us understand the toughened glass procedure. So, the purpose is when I break the glass it should break in a manner so, that I will get a small granules like fragments the SOP for this one is first I will be taking a specimen of 360 by 1100 mm without any holes cut outs or notches. You can see in the figure the my dimension is 1100 by 360. Next, second step is each specimen I need to take a takeout 5 samples to ensure my fragmentation toughened quality.

Next each test specimen shall be impacted using a pointed steel tool at a position of half inch that is 13 mm from the longest edge of the test specimen, at the midpoint of the edge until the breakage occurs. You can see in the figure and my longer side is 1100. So, I am taking a midpoint that is 550 and from the midpoint I am leaving half inch that is 13 mm and from there I am impacting.

And the tool what we use for impact you can see here, the examples of steel tools are hammer of about 75-gram mass, a spring loaded centre punch or either similar appliances with a hardened point. The radius of the curvature of the point should be approximately 0.2 mm. Once the setup glass and tools are ready next we will start our execution of the test.

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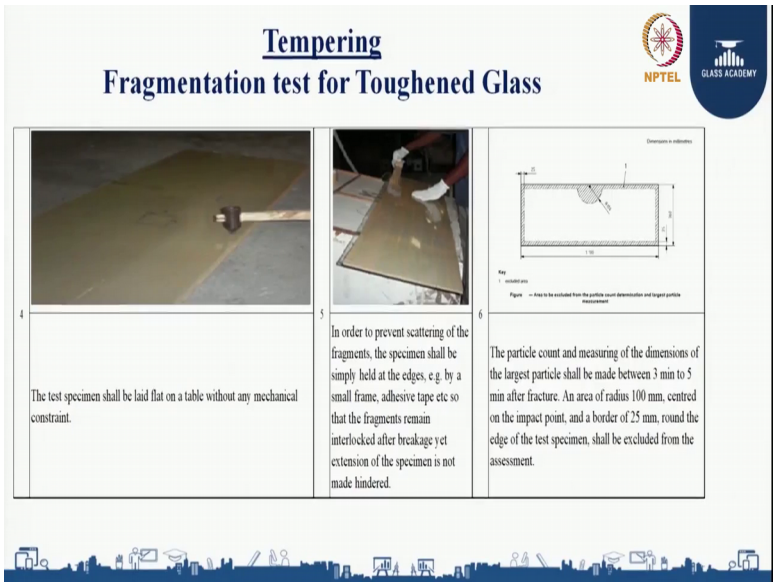

The test specimen shall be laid flat on the table without any mechanical constraint. In order to prevent the scattering of the fragments, the specimen shall be simply held at the edges by a small frame or a adhesive tape so, that the fragments remain interlocked after breakage yet expansion of the specimen is not made hindered. You can see in the figure that we are applying a tape adhesive tape so, that there is no scattering of the fragments.

Next the particle counter, and the measuring of the dimensions of the largest particle shall be made after the breakage of 3 to 5 minutes of the fracture. So, once after breakage, we should wait for minimum 3 to 5 minutes so, that all the fractures are get getting expanded. And an area of radius 100 mm centered on the impact point and a border of 25 mm around the edge of the test specimen shall be excluded. You can see in the figure I have excluded all the 25 mm on the periphery and from the impact point I am reviewing a radius of 100 mm.

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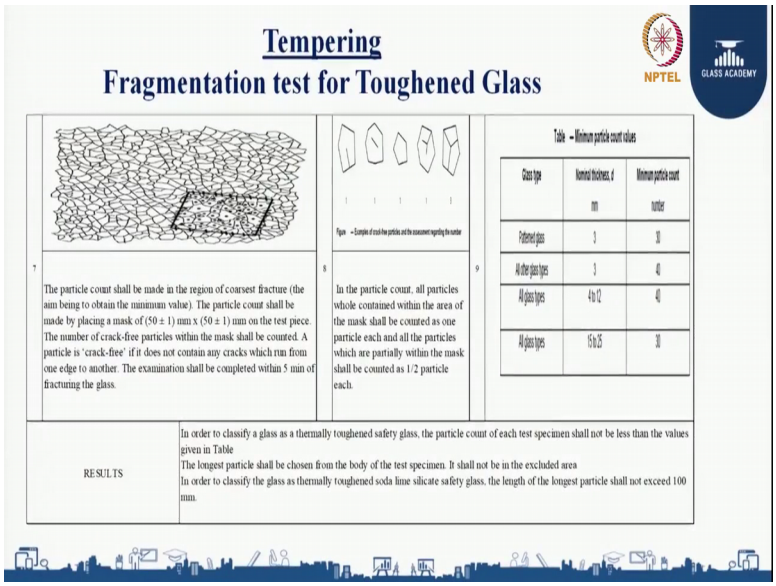

Now, how you are going to get the conclusion? If you see after my breakage, I am going to get a fragments in this particular pattern for a toughened glass. The particle count shall be made in the region of courses to fracture; that is, the aim being to obtain a minimum value.

So, after breakage I should select the area where my fragments are in minimum range. The particle count shall be made by a plus by placing a mask off 50 mm by 50 mm on the test specimen. You can see in the figure we have marked it 50 by 50 mm marking on the glass. After breakage we need to start counting the number of crack pre part the number of crack free particles within the mask shall be counted. A particle is called said to be crack free, if it does not contain any cracks which run from one edge to another. The examination shall be completed within 5 minutes of fracturing the glass.

So, I should count the number of particles within 5 minutes. And I should identify the crack free particles. You can see in the 8th point, these are the particles that are known as crack free. Examples of crack free particles and the assessment regarding the number. You can see in the figure there are different types of particles with different cracks.

In the particle count, all the particles whole contained within the area of the mask shall be counted as one particle. And all the particles which are partially within the mask shall be counted as half particle. So, at a time of counting, if I get any particle which is in half of the masking area and half in the outer area, I should be calculating that particular

particle as half particle. And you can see the minimum particle count. You can see in the table, if I am using any glass; if my glass thickness is between 4 to 12 mm the minimum particle count in a 50 by 50 square plate should be minimum 40 particles, 40 numbers. If I am getting minimum 40 particle means I am ensuring that the toughening process has been successfully completed.

Results. In order to classify a glass as a thermally upon safety glass the particle count of each test specimen shall not be less than the value given in the table. For example, if it is 6 mm thick I should get a minimum 40 particle. The longest particle shall be chosen from the body of the test specimen; it shall not be in the exploited area.

So, we need to identify the longest particle and it should not be in the excluded area. In order to classify the glass as thermally toughened soda lime silicate safety glass, the length the length of the longest particle shall not exceed 100 mm. So, basically I need to understand 3 points, at the time of conclusion, what are the particle count they I am good at I am getting? It should be minimum 40 if I my thickness is 4 to 12 mm. I need to see the longest particle, and it should not be in the excluded area.

And the longest particle length should be not more than 100 mm. So, this is how I am ensuring the tempered glass quality through fragmentation test. Next let us take the same fragmentation test for a heat strengthened glass. So, when I break a heat strengthened glass how the breakage pattern is going to be?

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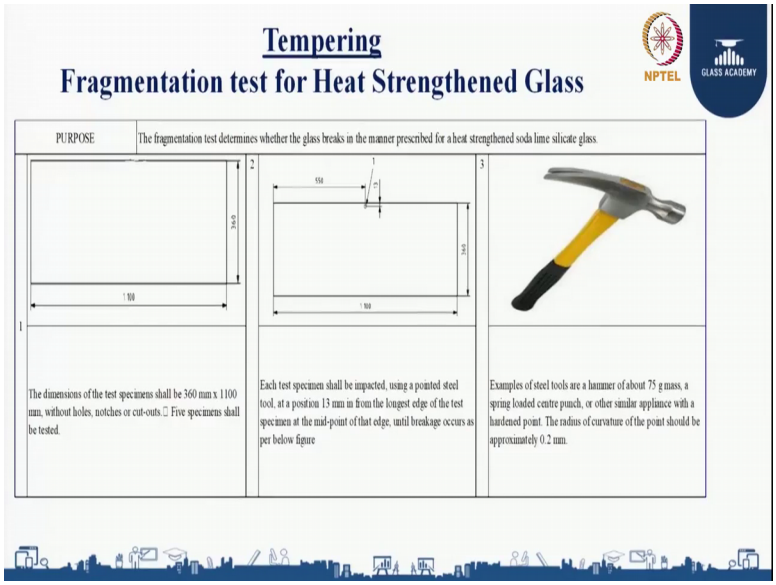

Now, let us see the similar test setup remains the same as compared to the toughened glass to the fragmentation test determines whether the glass breaks in the manner prescribed for a heat strengthened soda lime silicate safety glass. For this also we will be taking a sample of 1100 by 360 mm, I will be taking a 5 test specimens, I will be measuring the midpoint of the longer side; that is 550 mm and I will be leaving half inch from the edge that is 13 mm. With the help of punching tool, with the help of centre punch or any hammer I will be impacting the glass.

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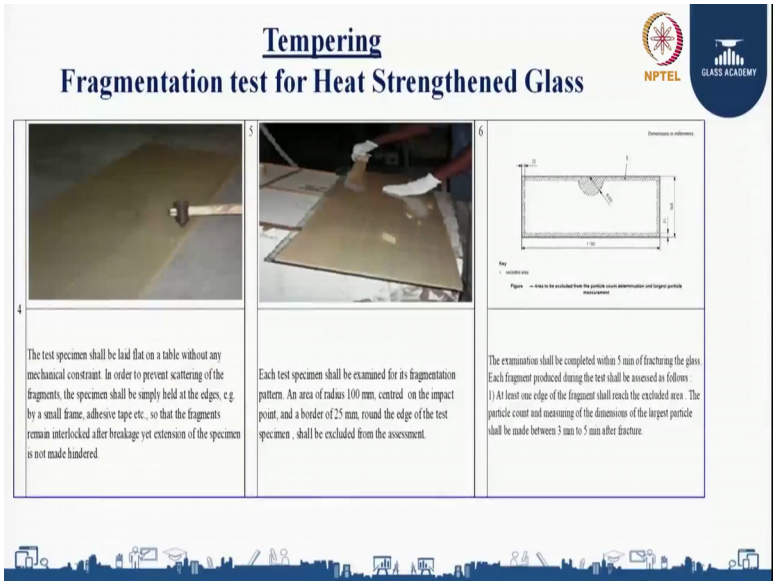

Before impacting I will be ensuring that there is no scattering of the particles. And I need to from the breakage point, I need to leave a 100 mm arc, and I need to exclude 25 mm on periphery of the glass. Here if you say in the 6th figure, the examination shall be completed within the 5 minutes of the fracturing the glass. Each fragment produces during the test specimen shall be assessed as follows. At least one edge of the fragment shall reach the excluded area. The particle count and the measuring of the dimensions of the largest particle shall be made between 3 to 5 mm after the breakage.

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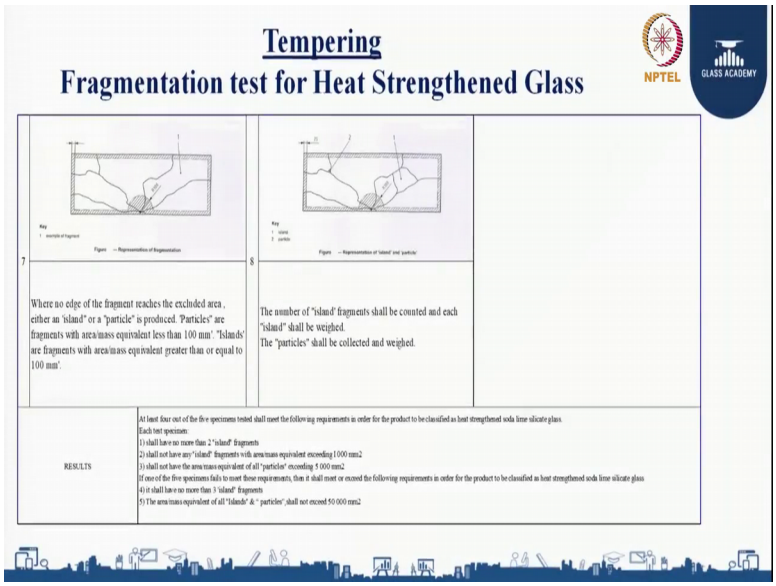

If you say when I impact a glass this is how a heat strengthened glass is going to break. You can say here in the figure 7 figure, where there is no edge of the fragment reaches the excluded area, either an island or a particle is produced. After the breakage if your fragment is not able to reach the excluded area. In that case, so, you are going to get either an island or a particle.

Now, particle is a fragment with area by mass equivalent less than or equal to 100 mm. When you are going to call a fragment as a particle. Means, when your area by mass is equivalent to less than or equal to 100 mm. And you are going to call it as a island; where area by mass is greater than or equal to 100 mm. So, I am repeating again, where no edge of the fragment reaches the excluded area either an island or a particle is produced. Particles are the fragments with area by mass equivalent less than 100 mm, islands are the fragments with area by mass equivalent great greater than or equal to 100 mm. So, when I am getting less than or equal to 100 mm. It is considered to be a particle when I am getting more than 100 mm it is considered to be an island.

So, once the glass got broken so, we need to see what are the number of islands and particles. The number of islands island fragments shall be counted, and each island shall be weighed. The particles shall be collected and weighed. So, after the breakage is happened, we need to see the breakage pattern, we need to see the number of islands we need to see the number of particles and we need to weigh the islands and particles.

Now, how we are going to conclude? At least 4 of the 5 specimens tested shall meet the following requirement in ordered for the product to be classified as the heat strengthened soda lime silicate glass. And the points are, one shall not have no more than 2 island fragments. Shall not have any iron fragments with area by mass equivalent exceeding 1000 square millimetre.

Shall not have the area by mass equivalent of all particles exceeding exceeding 5000 square millimetre. If one of the 5 specimens fails to meet these requirements, then it shall be meet or exceed the following requirement. In order for the product to be classified as the heat strengthened silicates soda lime silicate glass. It shall not have no more than 3 island fragments. And the area by mass equivalent of islands and particles shall not exceed 50,000 square millimetre.

So, what I was discussing? How you are going to conclude after the breakage pattern. You need to see what are the number of islands in a breakage pattern. It should not be it should be not more than 2, and the weight of the island shall not be more than 1000 square millimetre. And the weight of the particles shall not exceed 5000 millimetre. If one of the 5 test specimens fails, then how we are going to conclude?

So, there it shall not have more than 3 island fragments. And the weight of the or the area by mass equivalent of island and particles shall not exceed 50,000 square millimetre. So, this is how you are going to determine whether a glass is properly heat strengthened or not. Next let us understand the concept of bend or bow in a glass.

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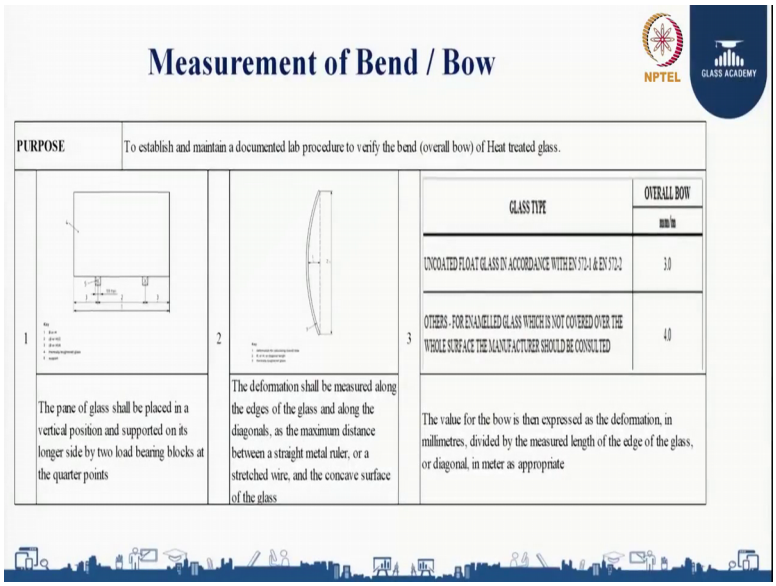

As the glass is passing through heating and cooling, in the heat treatment process the glass acquires bend or bow. So, this is one test. Now we are going to see how we are going to measure bend or bow on a glass. Purpose to establish and maintain documented lab procedure to verify the bend or bow of a heat treated glass. The bend or bow for a heat strengthened or a toughened glass remains the same. The SOP, the process or the setup remains the same. Let us understand.

The glass first of all we need to the pain of the glass shall be placed in a vertical position, and supported on it is longer side by 2 load bearing blocks at the quarter points. You can see in the figure; I am keeping the glass on a vertical position, and I am keeping 2 load bearing blocks. And I am positioning the blocks at the quarter points. Suppose, if my panel size is 1,000 mm. So, I will be keeping the glass vertically and I will be taking 250, 250 as my load bearing blocks.

Next, the deformation shall be measured along the edges of the glass. And along the diagonals as the maximum distance between the straight metal ruler or a stretched wire and the conquer circle surface of the glass. If you see in the figure, if my glass is having bend or a bow, when I am measuring with the help of a straight edge or a straight ruler, and I am try I am using a paper gaze. When I am trying to insert taper gauge between the glass and the straight roller, if I am able to find the gap between the glass and the straight roller that is the my bend. That is how I am going to measure. So, the deformation

between the glass and the straight roller will indicate will give and indicate about the bend. So, you can see in the figure second figure after the heat treatment process is over there is a gap between the glass and the straight roller. That is, that is we are going to measure with the help of taper gauge scale.

Now, how you are going to conclude whether a glass is within the limit of bend or it is beyond the limit of bend. You can see in the standard, in a meter 3 mm bend is allowed. If it is my uncoated float glass; for an enamelled glass 4 mm bend is allowed. So, the value for the bow is then expressed as a deformation in millimetres, divided by the measured length of the edge of the glass or diagonal in a in a meter as appropriate. So, when my panel size is 1000 mm as per the standard 3 mm bend is allowed. If my panel size is 2000 mm, 6 mm bend is allowed. This is how you are going to measure the bend in a glass. So, to summarize how we are going to measure the bend in the glass.

First we need to take a glass, we need to keep the longest side vertically and we need to have to say 2 supporting blocks at the quarter points of the size. Then we need to measure the deformation between the glass and the straight edge or the straight roller with the help of a taper gauge scale. As per the standard for a 1000 mm panel 3 mm bend is allowed.

So, we have seen how we are going to measure the bend in a heat treated glass. Now let us see a video that will even demonstrate.

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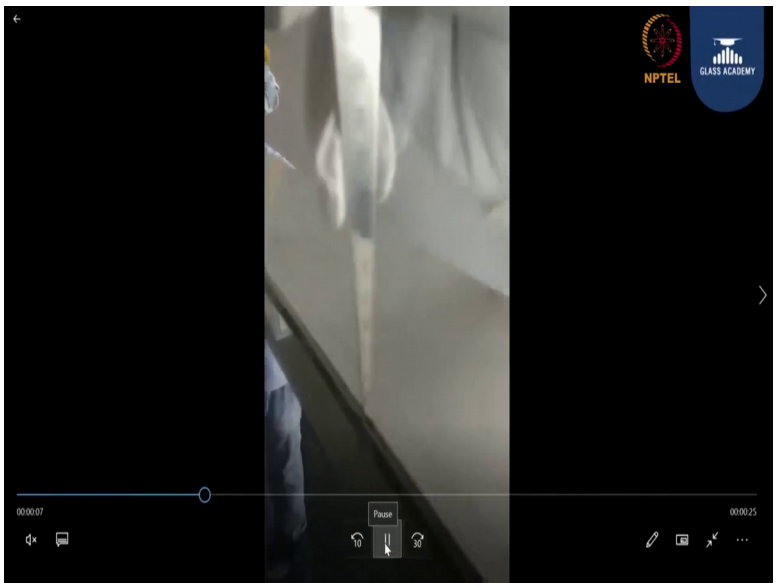

If you see, I have taken the longest side and I have kept a vertically and I have kept setting blocks at the quarter position. And I am measuring the deformation between the glass and the straight edge with the help of a tape gauge. You can see here my taper gauge is able to go inside up to 2.5 to 3 mm. So, you can say in this particular glass the bend is 2.5 mm. You can see the setup here vertically I am stacking, and I am using a set of blocks at the quarter positions.

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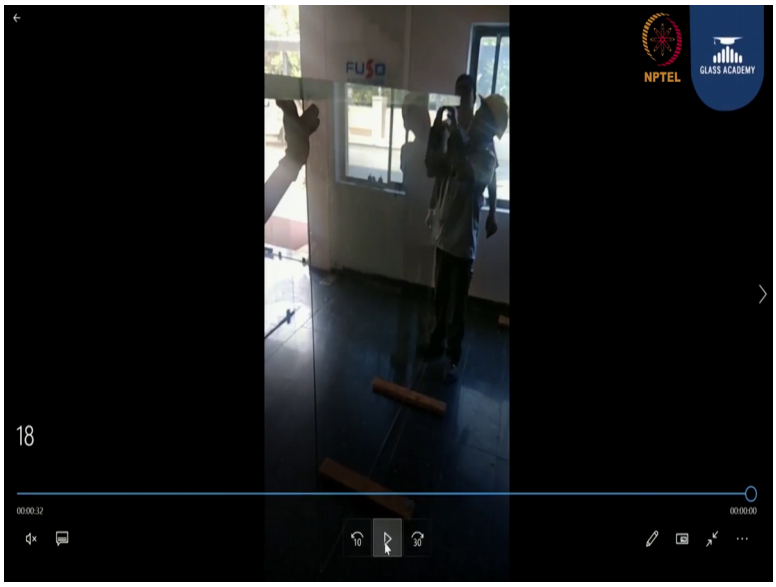

And with the help of straight edge ruler and a taper gauge I am measuring the bend, ok.

Now, let us understand the concept of roller wave. So, what is a roller wave? If you see the glass what we known as a heat treatment process, the glass is getting strength through heating and cooling. And the movement of the glass is on the rollers. As the glass is passing on the rollers, there is always chances of role impressions coming on the glass. Now we need to understand how you are going to measure the roller wave. When a glass is having heavy roller wave, you are going to get a distorted image. So, we need to see how far we are going to control the roller wave and what is the tolerances for roller wave.

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Now, let us see one more video. If you see, I am taking a glass and I am making sure that as the glass is moving on the roller that inside. The bottom surface will be in contact with the roller. So, I need to place the bottom surface on top of the glass, and the measurement of the roller wave should be perpendicular to the direction of the glass.

Generally, we send the glass width parallel to furnace. At the time of measuring the roller wave, I should make sure that the glass is whichever the surface in contact with the roller and keeping on the top. And I am using a flatness table to ensure there is no, to ensure I am nullifying the gravitational force. And with the help of a roller wave gauge, you can find your roller wave gauge. I am replaying here this video; you can find here the roller wave gauge which has 2 dial gauges. If you see the centre gauge. Right now it is showing 0.06, 0.05 you need to focus on the centre gauge it is showing 0.06 again.

And if you see on an average it is fluctuation between 4-0.4 to 0.07. So, the roller wave is is nothing but the glass is moving on rollers. And it is going through peaks and valleys. So, we need to calculate the summation of the peak and valley. If you see the minimum value in this initially it came point naught naught and maximum value what it as showing this 0.07.

So, the roller wave is nothing but the summation of the peak and the value. So, with the help of the centre gauge roller wave equipment we can say that, the roller wave in this

particular glass is 0.07. You can see, you can again recheck the roller wave you can see the starting starting is 0.02.

Now it is going, you can see you you focus on the centre dial gauge. Whichever we need to we need to capture the minimum and the maximum value, and the maximum we came out to be 0.07. So, the roller wave in this particular glass is 0.07. So, to summarize in order to measure the roller wave gauge. To summarize in order to measure the roller wave gauge, I need to make sure the glass surface which is in contact with the rollers to be kept on top. The measurement of the roller wave gauge he is done with the help of roller wave gauge.

And the glass should be placed on a flat flatness table to ensure or to nullify the or the gravitational force. And we need to move the equipment the roller wave gauge along perpendicular to the glass surface. And we need to note down the minimum and the maximum value in the dial gauge. And it should be the summation of the peak and the valley. If you see the roller wave gauge for the float glass in accordance with e n 1, e n 572 and e n 572 part 1 and part 2 it is 0.3 mm. And for the enamelled glass it is 0.5 mm.

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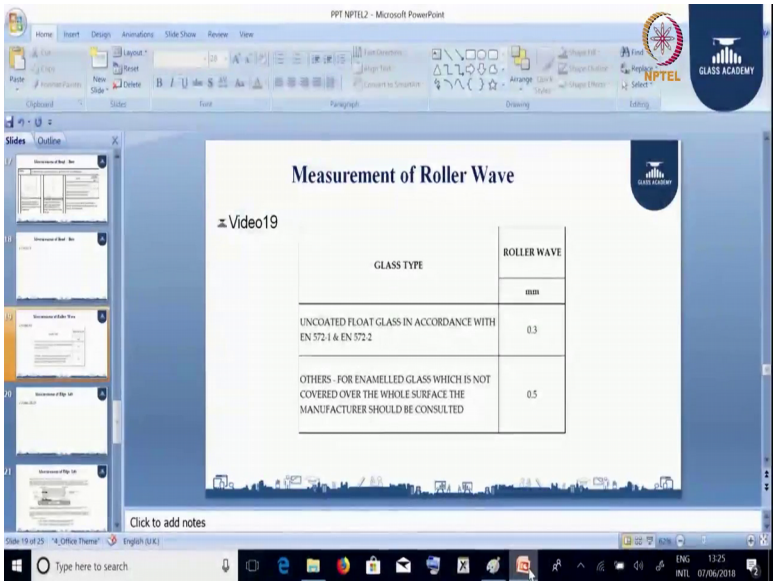

Now, let us understand what is edge lift. In order to understand this, let us take one more video which will elaborate the edge lift. What is edge lift and how it is going to come on a glass. Edge lift is nothing but a distortion what we get on edges. In order to measure the equipment, it can be done in 2 ways.

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If you see the first way; where with the help of a knife edge and the pillar gauge. I am trying to measure the edge lift. The procedure for this one is, I need to take a glass on a flatness table, I need to make sure that generally edge lift you get on the top surface.

So, I need to make sure that the edge the glass is facing on the top side in the furnace means, the measurement of the edge lift should be on the top surface. And it should be placed on a flatness table by leaving a 100 mm hanging in the table, and with the help of a knife edge and a feeler gauge, I can measure the edge lift. The measurement should be perpendicular to the direction of the glass. If you see here I am just replaying. If you see here I have taken a knife edge and I am trying to insert the filler gauges into the scale. Whichever scale is not able to fit inside the knife edge, that shall give me my edge lift. If you see in this particular video my edge lift in this glass is 0.10 mm.

So, this is how you are going to measure the edge lift with the help of a feeler gauge and a knife edge. Now let us understand the edge lift concept with the help of edge lift gauge. If you see in this figure in this video, there are 2 dial gauges; one is edge gauge and the second one is centre gauge. When I am moving the edge lift gauge on the surface of the glass, you can find out there is a changes in the values of the end end gauge and the centre gauge.

The concept or the working instructions for this particular edge lift gauge is, I need to subtract the centre gauge reading minus the end gauge reading. That will give you my

edge lift value. We need to understand if my value is coming positive the edge lift is on the bottom surface. And if my edge lift value is coming negative my edge lift is on the top surface. I am just replaying the video. If you say the end gauge it is showing 0.12 and the centre gauge it is showing 0.05. If you focus on the readings, we need to identify what is the what is the differences in the readings.

You say it was for the end gauge it was 0.12 and the centre gauge it was 0.07. So, if I send, if I subtract, centre gauge minus edge gauge that is 0.07 minus 0.12. So, my edge lift is it is coming to be around 0.1, 0.07. And it is a minus value, which indicates the edge lift is on the bottom surface. Minus indicates it is on the top surface and plus indicates the edge lift is on the bottom surface.

Now, the same concept what we have discussed so far you can see here.

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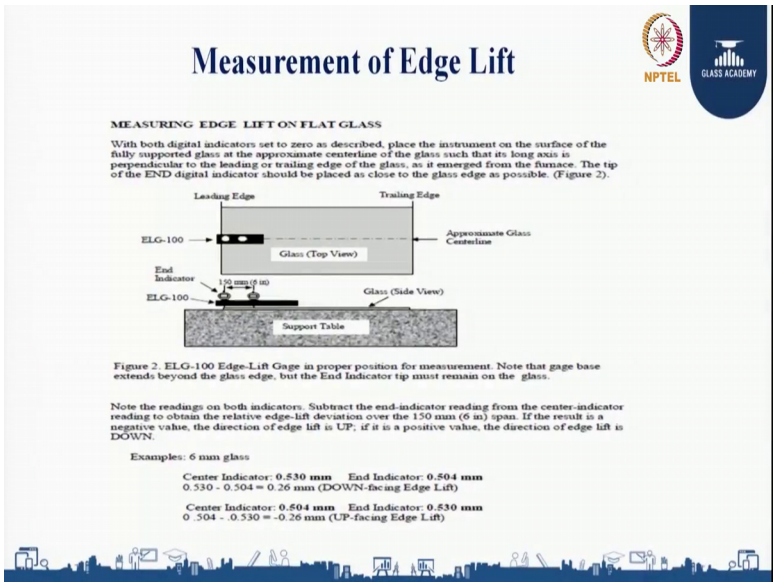

Measurement of edge lift gauge through measurement of edge lift on flatness table with the help of edge lift gauge. I am taking the glass and I am kept placing on the flat support table. And I am moving with the help of edge lift gauge, I am moving the gauge across the surface of the glass.

And I am I am making sure that the end gauge is is exactly matching the end edge of the point. If you say with both dial gauges indicate set to 0 as described place them, place the instrument on the surface of the fully support glass at the appropriate centre line of the

glass, such that it is long axis is perpendicular to the leading or trailing edge of the glass. As it is emerged from the furnace, the tip of the ended end end digital indicator should be placed as close as the edge as possible.

So, when I am taking a glass and placing on the flatness table, and I am placing the end gauge as close as possible to the edge of the glass, you can see in the figure. So, this is my end indicator and the other one is my centre indicator. So, the readings, for example, I am measuring on a 6 mm glass. The centre indicator came to be 0.530 mm and the end indicator came to be 0.504 mm.

So, my actual edge lift comes out to be it is centre indicator minus end indicator, which is 0.530 minus 0.504, which is positive 0.0026. Which indicates downside, I am getting the edge lift on the downside. The similar case if my centre indicator is 0.504 and end indicator is 0.530, when I am subtracting centre indicator minus end indicator if I am getting a negative value which indicates my edge life in the top is in the top surface.

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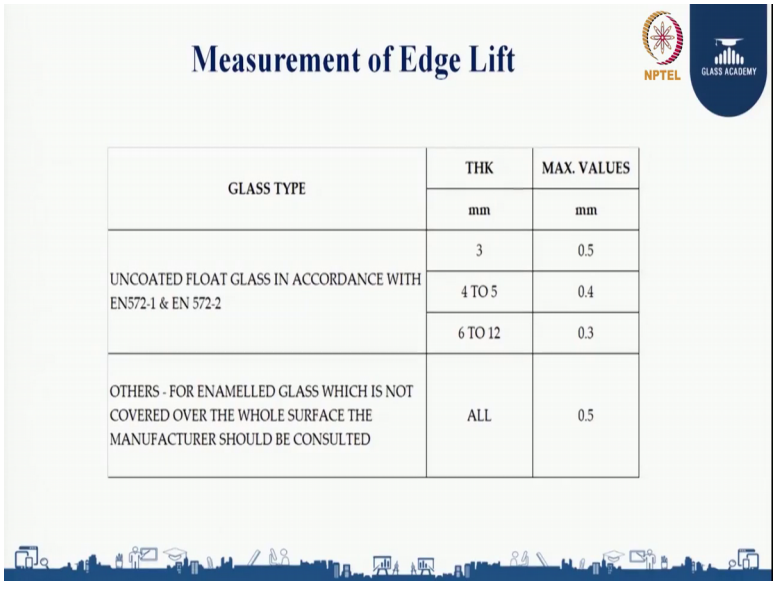

GLASS TYPE	THK	MAX. VALUES
	mm	mm
UNCOATED FLOAT GLASS IN ACCORDANCE WITH EN572-1 & EN 572-2	3	0.5
	4 TO 5	0.4
	6 TO 12	0.3
OTHERS - FOR ENAMELLED GLASS WHICH IS NOT COVERED OVER THE WHOLE SURFACE THE MANUFACTURER SHOULD BE CONSULTED	ALL	0.5

You can see the edge lift values as per the tolerances or the standards. If my glass is a float glass, if my glass thickness is 3 mm, the maximum values of edge lift allowed is 0.5 mm. And if my glass thickness is between 4 to 5 mm, the edge lift maximum value allowed is 0.4 mm. And if my glass thickness is between 6 to 12 mm, the edge lift maxim allowable is 0.3 mm. And for the enamelled glass it is 0.5 mm.

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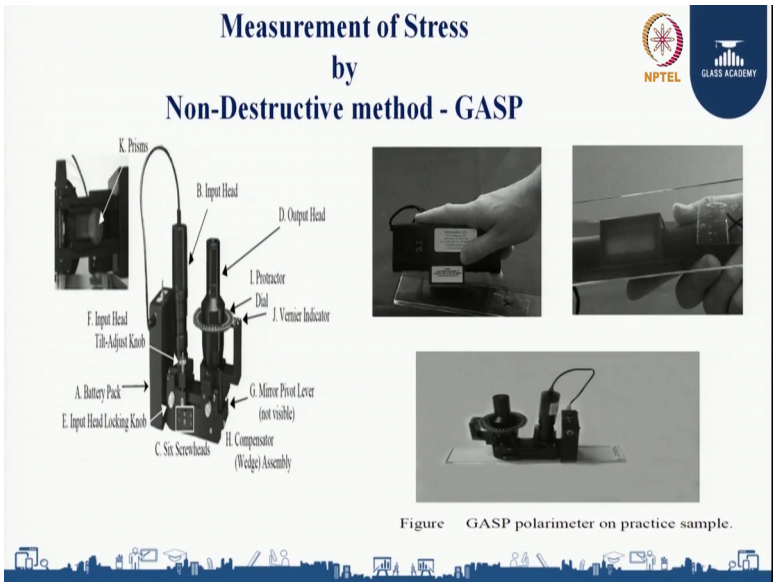

Now, let us understand the concept of stress in the glass. As we have discussed during the heat treatment process, glass acquires a strength the strength in the form of heating and cooling. When I went when someone gives you a annealed glass HS glass or a toughened glass; by visually you you cannot a determine which is annealed, which is h s which is toughened. So, to identify or distinguish which is what, we have 2 methods. One is known as a destructive method what we have seen earlier that is a fragmentation test where we are going to break the glass.

And now, but at straight levels it is always not possible to keep on breaking the glasses. So, we need to understand the concept of non-destructive method. That is with the help of GASP glazing angle surface polarimeter. This is one equipment that is used to measure the stress in the glass that is being induced during heat treatment process.

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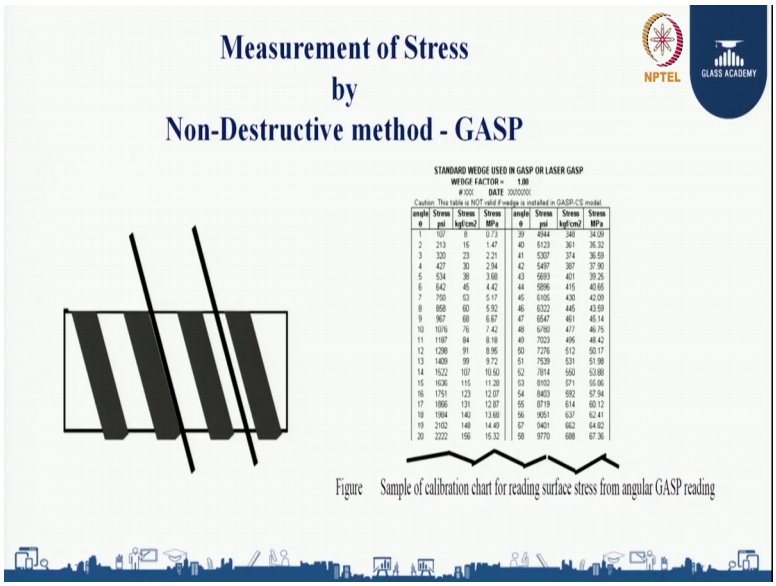

So, this is how a GASP will look. It will have different you can see the parts of this equipment. So, I need to in order to measure their stress levels in the glass, certain points I need to keep in mind. First thing, the measurement of the stress value stress should be always on the tin surface; that is, the glass which is in contact with the rollers on that surface I need to measure the GASP. That is a stress stress value. Second pointer, I need to I need to identify which is the tin side and then which is the non-tin side.

In order to measure the GASP measurement, always the measurement should be on the tin side. If you say generally any glass the glass will be moving on during the manufacturing of the glass, the glass will be moving on a molten tin bath, where one where the top surface of the glass will be facing the air side, and the bottom surface will be in touch with the tin.

The glass which is in touch with the tin is known as the surface, which is in touch with the tin is known as tin side surface, and the glass which is which is in the top side is known as top surface. The measurement of GASP which should be always on the tin side. So, and by visually in the glass one may not be able to identify which is the tin side and which is the air side. So, in order to identify we have one equipment known as tin side tester. You can see in the figure, that is at tin side tester when I place on the glass surface, if I am getting a hazy impression that indicates it is at tin side surface. If I am not able to get any hazy impression that is my air surface.

So, the measurement of GASP shall be on tin surface. You can see in the third figure. This is how I am going to place the glass after identifying which is the air side which is the tin side, I need to place the GASP equipment on the tin surface. If you see on the gas, because you you have this protector protector angle. So, I need to make sure that these if you see these are the fringes, I need to make sure that the stress lines or the fringes on the GASP, and the and the gas polarimeter angle should be parallel which with each other.

Like in the like as shown in the figure. When I am getting perfect parallel of the GASP angle and the stress angle, that is my stress value. If you see in the table there is corresponding table, where my angle is matching with the stress line. For example, for example, if my angle is at 45 degree and the corresponding equivalent stress value is 6105 that is a unit is pounds per square inch. They are similarly it is equivalent to 42.09 when it comes to mega Pascal.

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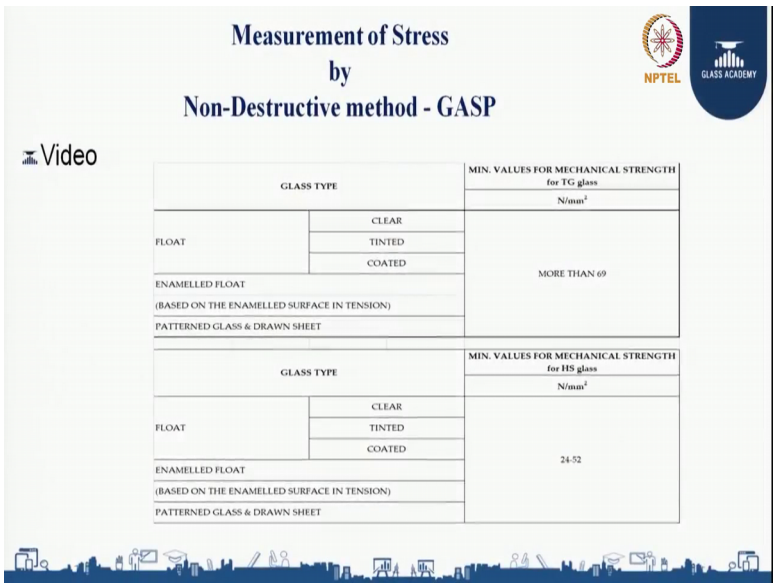

So, in order to measure the stress levels in the glass, for a toughened glass, the stress value is considered to be more than 69 MPa or Newton per square millimetre. And for a heat strengthened glass, the stress value is considered to be 24 to 52 newton per square millimetre or MPa