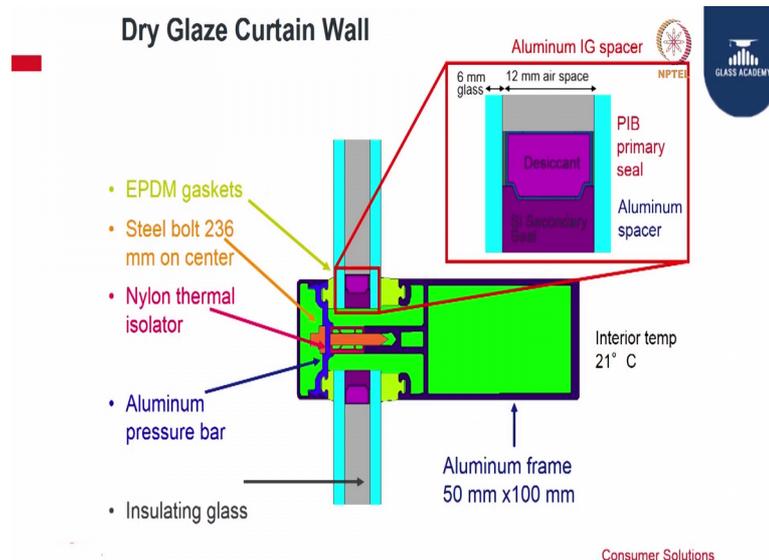


**Glass Processing Technology**  
**Prof. Mr. Ravishankar**  
**Department of Civil Engineering**  
**Indian Institute of Technology, Madras**

**Lecture-44**

**Silicone Sealant for Insulated Glass Part II**

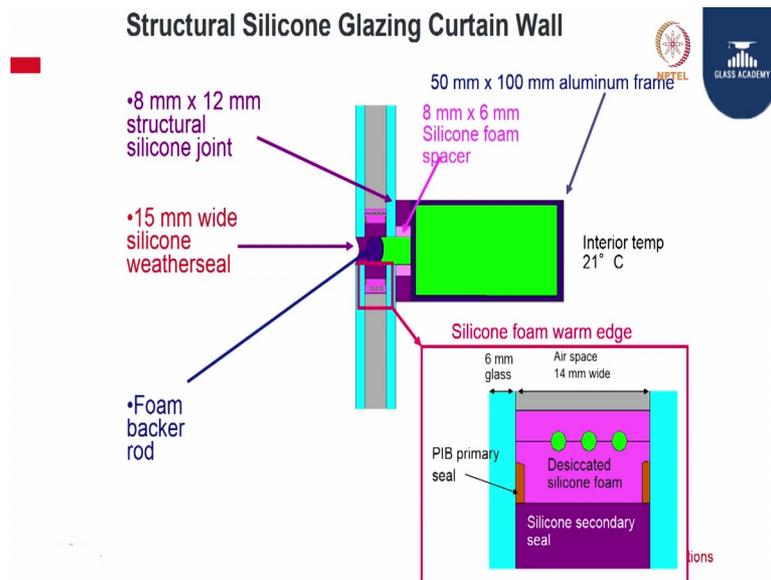
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I am going to talk about the fixing methodology of DGU and then we will go into the details of every seal. So, this is why I am, you know quickly taking you through is to give you a feel, that how you fix a DGU also in parts or conducts temperature like, climate like, like hours which is hot outside. So, you have a thermal conductivity which happens when you have systems which are dry fixed in comparison to the structural glazed facades.

So, you have an EPDM gaskets system and this is the pressure plate which is being used and you also have a thermal isolator and then you know, this system is fixed like a dry you do not use a silicone you use gaskets completely fixes. So, you need to maintain an interior temperature of 21 degree generally the aluminium frame is of this size and there is a DGU used, and the DGU has got 6 mm glass 12 mm air space dc can primary seal and secondary seal this system is called as a dry glaze system.

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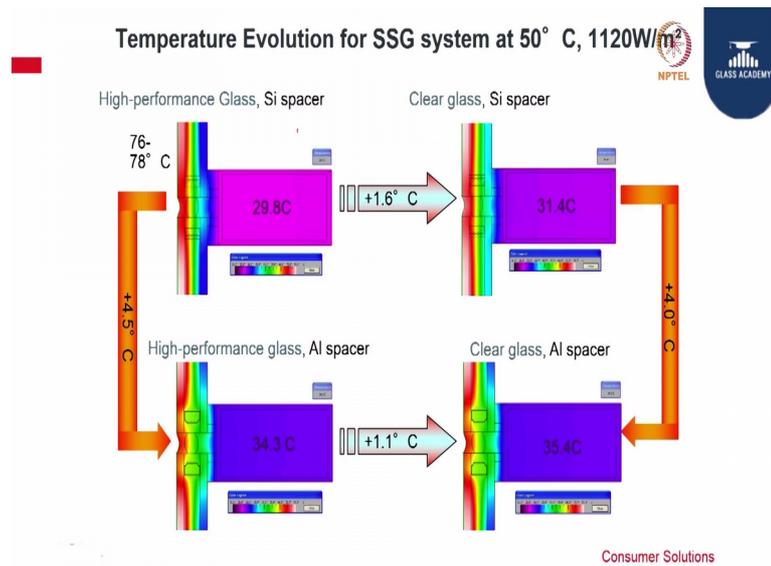
Now, we will see what happens, when you subjected to the, you know, atmospheric conditions and before that I will also take you through the other system called as, silicone structural glazing curtain wall system. If you see here, there is a silicone secondary seal under desiccant system, aluminium spacer, here what we are looking at is structural silicone glazing curtain wall and we are also talking about a system, wherein you do not have a mechanical capping from outside.

There is no conductivity which happens, because of that and you have the glass structurally bonded to this, aluminium using silicone sealant and there is a weather seal. So, this is thermally completely you know isolated. So, you do not have any, connections happen here.

So, the joint dimensions are mentioned this is the byte, and this is the blue line thickness and here it is secondary seal is here. Inside the DGU, and also there is a backer road applied for the weather seals.

So, there are 3 different silicone which has been used or the sealant, has been used to hold this unit together same amount of aluminium frame and what we are talking about here is also a different, desiccated silicone foam spacer this is called as a thermal spacer. What happens, for the temperature evolution for SSG system at 50 degree imagine there is a 50-degree centigrade, and you have a high-performance glass with the silicone spacer and you have a high-performance glass with aluminium spacer.

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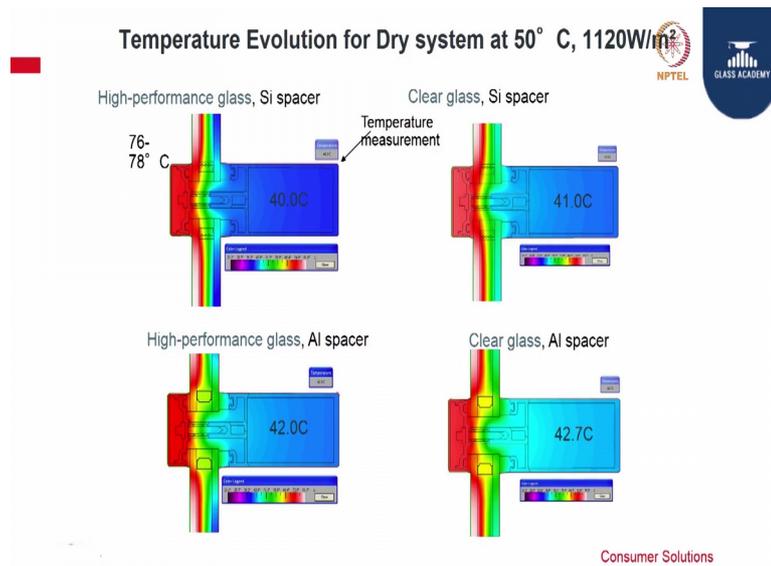


Here, we are talking about a difference with the same way of doing the system and then see the temperature difference. So, what you have here is when you have a temperature evolution 50 degrees you get 29.8 degrees when you use a thermal, silicone foam spacer compared to the aluminium spacer which is 34. So, there is a difference of almost 5 degrees here, you know 4.5, yeah 4.5 degrees difference where the temperature becomes warmer, compared to the using a silicone foam spacer.

So, here it is a clear glass comparison. So, here it is 31.4, because there is a clear glass, there is no coating naturally the temperature is going to go up and with the aluminium spacer you get 35.4 which is around 4-degree difference. So, what it essentially shows is, shows are just by using a foam spacer from a silicone foam spacer, you can also the reduce temperature what is, the conductivity have what happens through the system.

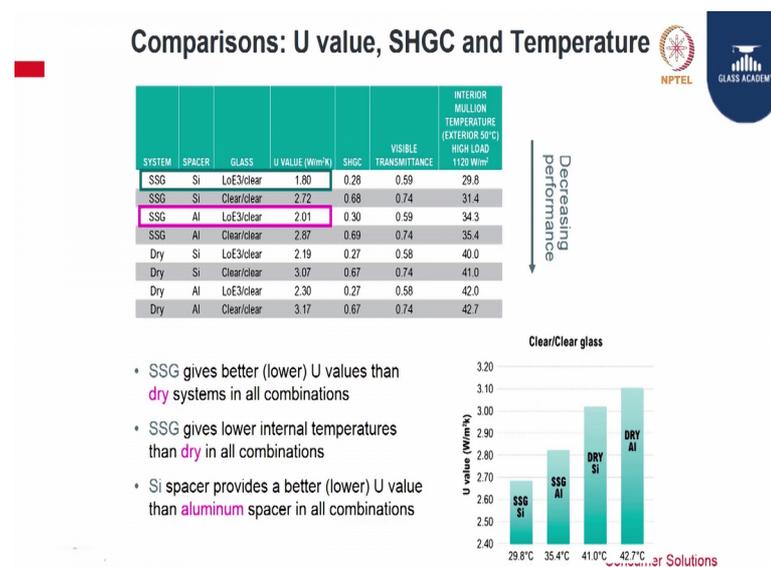
So, this is essentially talking about just by doing a difference of silicone spacer, with a high-performance glass, clear glass. So, there is always a difference of 1.6 and within these 2, 4 degrees and 4.5 degrees. And a dry system this is wet we saw the dry system we are going to see the wet system which is a silicone glazing this is the gasket fixing.

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On the dry system if you really look at. So, the temperature gets to 40 degrees, because of the conductivity which happens, because of the pressure and capping system, with a silicone spacer and if you use an aluminium spacer it becomes 42. So, the difference of 2 degrees noticed by changing the spacer and where you use a clear glass instead of high-performance glass. This difference again becomes 1.7 degrees, but the temperature essentially becomes more, because there is no high-performance coating glass is used here.

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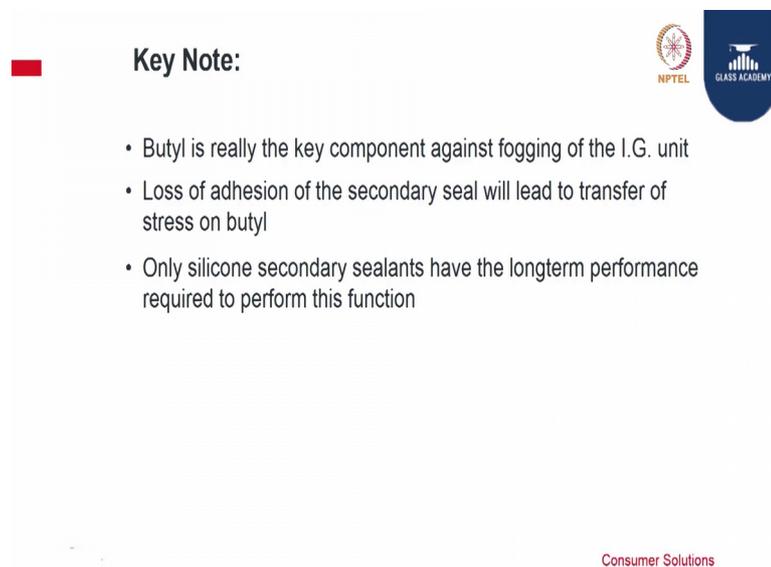


So, essentially what it talks about is, just by doing a proper selection of the spacer. As well as, the way it is bonded to the structure you get very good, temperature reduction and silicone structural glazing again gives you the best, possible thermal reduction there is a way of doing the bonding applications. So, you know some of the things what we saw there is that is the same thing put here.

So, this also talks about the U value, if you have a silicone spacer in an aluminium spacer then, how is what is the reduction of the U value, or you know how it becomes really good to have a lower u value, because you get 1.8, this is 2.101, when you do an aluminium spacer versus a silicone spacer.

So, what we are talking essentially is you get a good durability; you give it's, it gives better U values than dry. So, structurally glaze systems give you better U values then a dry fix system. So, SHGC gives lower internal temperatures than dry in all combinations. You use any combinations of dry fixing and do structural bonding naturally you see silicone spacer provides better U value than the conventional aluminium spacers.

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The slide features a red square icon on the left, the text 'Key Note:' in bold, and two logos on the right: NPTEL (National Programme on Technology Enhanced Learning) and GLASS ACADEMY. Below the text is a bulleted list of three points. At the bottom right, the text 'Consumer Solutions' is visible.

**Key Note:**

- Butyl is really the key component against fogging of the I.G. unit
- Loss of adhesion of the secondary seal will lead to transfer of stress on butyl
- Only silicone secondary sealants have the longterm performance required to perform this function

Consumer Solutions

So, the key note here is if you remember we saw the key note on the first thing about sealants and, essential way of doing things on seal applications. Now we are talking about the key note here is butyl is really the key component against fogging of the I.G unit any stress on to the butyl and there is a failure that can lead to I.G failure. Loss of adhesion in the secondary seal will do stress of stress on butyl only silicone have the best

long-term performance.

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**Making a high quality IG Unit?**

But that's easy, you just:

- Take Prepared glass (clean, edge deleted)
- Attach a spacer
- Fill with desiccant
- Apply enough of the PIB
- Press the glass
- Apply the 2nd seal

But there is much more than that behind quality IG units...



Consumer Solutions

So, now, we will come to the you know application part. So, we saw the chemistry part, we saw the different tastings and experiment part, we also saw, how a combined system of primary and secondary seal gives, with silicone and the PIB gives the best durability. We also saw the base of fixing the DGU with a dry and the wet glazing and we also saw the effect of that to the U value and we also saw was by choosing the right coating, how the U value can be reduced and also the solar heat gain can be reduced.

So, these are all essential part of DGU, but while coming to the manufacturing of, DGU, the application is very critical. So, how you do it is take a prepared glass, clean, if it is needing an edge deletion, delete it properly using the proper gage. You know grinders or the wave mechanisms suggested by the manufacturer attach a spacer.

So, before attaching the spacer you need to, you know attach the spacer and make it to the size of the glass and then clean the spacer, fill the desiccant apply enough of the PIB around the perimeter of the, spacer. Press the glass, you know press the spacer, press the glass and apply the secondary seal either by manual or by robotic, but there is much more than what this you know, behind this I.G units.

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**Obtaining High Quality, High Performance IG Units is essentially a matter of...workmanship**

Top 3 reasons for IG Unit failure\*:

- Workmanship
- Workmanship
- Workmanship

• → Important in ANY IG production – regardless of the secondary sealant type – and should be followed to produce high quality units

\*Citing Tracy Rogers, Edgetech IG, IGMA Preventing Insulating Glass Failures, 10 September 2007, Atlanta, GA

Consumer Solutions

So, what is the top 3 reasons for I.G unit failure the top 3 reasons for I.G unit failure is workmanship, workmanship and workmanship. So, it is very-very important, you can design you can choose a right product, but if you do not apply or the workmanship is not good you will essentially end up with a very bad quality of a DGU. Any IGU production regardless of the secondary sealant type, you know it should follow a high-quality, you know production process.

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**Insulating Glass Unit - Performance Influencing Factors**

1. Spacer
  - a) Type
  - b) Frame Corner assembly and Joint sealing
  - c) Desiccant
2. PIB-Application – Quality
3. Pressing of the glass panes
4. 2nd Seal – Quality
5. Transport
6. Other Production Factors (primarily operational parameters):  
Proper Quality Control Procedures, Adequate Unit Management after Products, Proper Installation, Setting Block Support, Depth of Sash, Venting of Sash, etc.

Consumer Solutions

So, what are the things which are going to influence the performance of DGU. So, the

spacer is a very critical component here, again. So, if you look at the spacer the type of spacer uses, how do you, how you join them, how you fill the silicone desiccant into the spacer. They are all very critical I have a slide to run through the spacer which I will take you through PIB application.

So, how you apply the PIB; so, this is a very small amount of a primary seal applied on the you know spacer. So, and there are standards which talks about, what is the minimum grams per running meter you should have which is approximately around three grams per running meter you should get minimum and then, there is a width and the thickness, which is specified it talks about say 4 or you have to fill that complete band, which is good for a long term durability and also the thickness of say 0.3 or 0.4.

So, which is so the, it talks about 2.7 or 3grams for running meter is per size. So, you have to you have to apply it accordingly, pressing of the panes the glass panes should be properly press. So, they are coming in a good contact with the primary seal and the spacer properly then apply the secondary seal. The one more thing which is also essentially important is before applying the secondary seal we should ensure that the spacer is clean.

So, the spacer cleaning is very important, to get good bonding of silicone to the glass edges as well as to the spacer, transportation is key, we need to transport only when the unit is, the sealant is cured completely and if you do a transportation.

Before that, there are a lot of stress which will come on to the sealant due to the vibration which happens, during the transportation and that can impart or you know that can affect the adhesion of sealant to the substrates and what you will essentially have is the gasket are not a bonded material. And also, when it is being essentially installed it is also important for us to understand.

So, how it has been installed what type of a metal which is coming in contact with the secondary seal of the DGU and you know how much is the depth and how it is going to be perimeter sealed with. So, those things are also important to understand.

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**1. Spacer type can have an important effect on longevity of IG unit**

- Thermal stress induces shear, tensile and peel stresses in edge seal caused by differential movements between spacer and glass
- CTE (coefficient of thermal expansion) varies strongly between materials: ( $10^{-6}/^{\circ}\text{C}$ )
  - Stainless Steel: 10.2-11.4 (others: 12.9-14.0)
  - Aluminum: 23.8
  - Glass: 8.0
- Finite Element Analysis simulations:
  - IG unit size 1.49 m x 2.13 m (patio door), same aspect ratio as the 0.35 m x 0.50 m test panes
  - Low temperature: corners pulled inwards, bending angle  $>90^{\circ}$
  - High temperature: corners pushed outwards, bending angle  $<90^{\circ}$

Corner deflection of aluminum spacer frame (exaggerated by factor 100)

So, I will quickly take you through some of that. So, the thermal stress induces, shear we are talking about the, spacer which is an important thing and we have a longevity of I.G unit. So, there are different types of, spacers you can have, so thermal stresses actually, because it is metal, it is going to conduct, the heat. So, there is going to be a differential movement between spacer and glass as well.

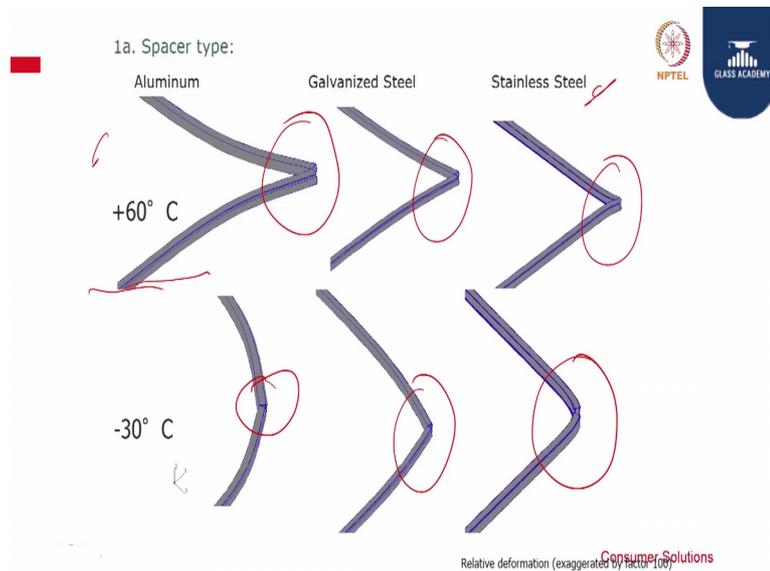
So, essentially there is going to be some movement when it happens. So, there could be a failure in the primary seal. So, the stainless steel has got 10.2 to 11.4, you know, millimetre per meter, per degree centigrade 10 raise to minus 6 aluminium has highest and glass is 8. So, if you see the combination when you do glass and the aluminium there is a differential movement which happens, because of these values, ok, 23.8, this is 8 and whereas, these two are close.

So, stainless steel spacers when glass the differential movement is lower. So, this is the stimulation done on a finite element analysis. You know on a lower, room temperature and a higher temperature when an aluminium spacer is subjected to, you can say here at lower temperatures size minus 30 this get shrunk, it becomes you know, shrink and this is the normal temperature and this is stimulation.

This is slightly absorbed you know, made it big, but this is what essentially happens when it becomes plus 60 degree centigrade it expands. So, you can see the change of behaviour on the corner. So, at lower temperature its pulled inverse at high-temperature

pushed outwards. So, its bending angle is, you know this is greater than 90 this is, less than 90. So, this is what happens with aluminium, you can see this, this galvanized steel is better stainless steel is the best.

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### Spacer Frame Corner Assembly and joint sealing, desiccant

- Spacers able to accommodate part of the movement of the IGU – warm edge spacers
- Tight spacer connectors: ideally banded, if welded: no gaps or steps
- Corner Keys need proper attention with PIB
- Butt-joint connection on long edge of IG unit
- Speed of bending: slow to avoid micro-cracks in spacer corners depends on ductility of material – Al can be bent faster than stainless steel
- Inject butt joints and desiccant filling holes with PIB for better sealing
- Enough desiccant, free of moisture inside spacer

So, same thing on the lower temperature aluminium, the aluminium is steel and stainless steel ok, but essentially in India we use mostly aluminium, but you can also look at other materials like stainless steel, which can give you a much-more better, IGU long-term performance and also the spacer frame corner assembly and joint sealing.

Essentially, we applied primary seal along this edge and this has to be completely nicely filled with primary seal and then this helps to bond the spacer to the glass and also there should not be any air gap or you know leakage. So, this should be nicely, you know fully filled in.

So, spacers are able to accommodate part of the movement of the IGU like warm edge spacers. If you have, they do not have much of a differential movement, because they are not metal essentially and also if you are doing a bending, and or we are doing connecting of the spacers. So, no gap should be there or steps should be there. So, corner keys again they need attention with PIB any joint area should be completely sealed with the primary seal to avoid any moisture penetration.

So, doing a butt joint do it on the longer edge middle of the you know long edge rather than on the short edge. So, because when they are subjected to stress the short edge, gets you know, differential load, though you may have more stresses on that speed of bending how you bend the spacer, you know sometimes you do it, fast it may, lead into micro cracks. And then essentially the breakage of the spacer, when it is in use and then the essentially the failure of the DGU.

Also any joints you fill it with PIB enough desiccant also to be filled inside the spacer, area to avoid you know keep the air, drive which is inside the DGU or since there are some moisture penetration again the desiccant helps to absorb them primary seal we are coming to the second one the primary seal which is already glowing.

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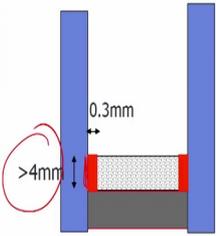
**2. Primary seal: Probably the single most important parameter**

PIB type:

- Long term heat- and UV-stability
- Good glass adhesion
- Low sensitivity against water
- Lower viscosity PIB: better results in initial testing, but do not perform as well in the long run, especially when exposed directly to sunlight (e.g. roof glazing or structural glazing)

Equipment:

- Maintain & clean PIB seal applicator
- Monitor extrusion pressure & temperature
- Monitor application speed (PIB seal must wet-out spacer and not be 'pulled' as a string)



Bead:

- Avoid skips
- Good surface wetting and flow during glass pressing
- Minimize air inclusion
- > 3g/m
- > 0.3 mm thickness and > 4 mm depth (bite)

Visual control PIB application quality by Trained personnel, understanding importance of requirements

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So, this is a very-very important seal for DGU to give long term, you know durability against fogging. So, it has to have a good heat and UV stability it should have good adhesion to the glass and the spacer it should be low sensitivity against, water and the lower viscosity PIB. So, better results in initial testing, but you do not perform a long run. So, if you have a material, PIB of lower viscosity PIB it is easy to apply, but it will not, it will have a tendency to run down, with time so, directly to sunlight or roof glazing or structural glazing.

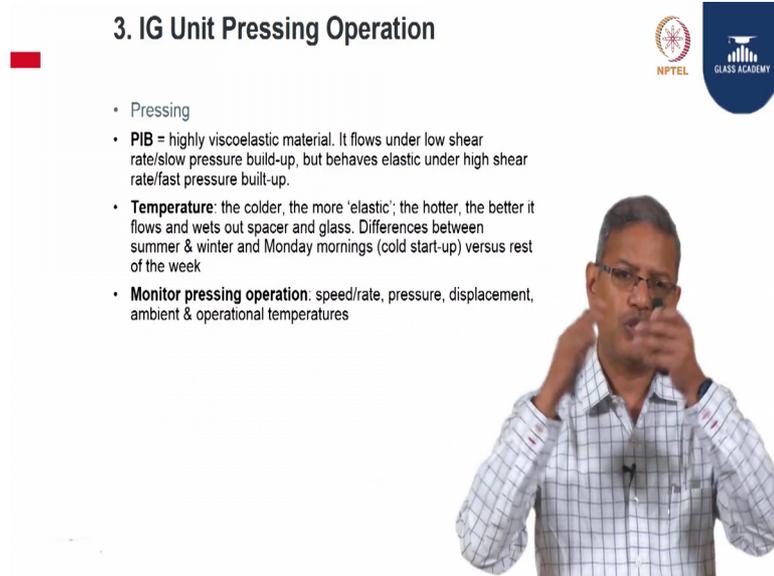
So, and also on the equipment side maintain the clean applications, when you see some of the PIB application machines, they are all having the, you know the cured material on the belt or on the edges it will not allow a good uniform application of PIB extrusion pressure and temperature is critical. So, maintain the temperatures it nicely comes out and then keep the pressure.

So, that, it touches a nicely fills that, monitor application speed do not run it. So, fast that you are unable to fill it properly and not to be pulled, as a string it should, it should be should get out the space or it should not be like a line.

So, these are some of the guidelines greater than 4 millimetre of this width and 0.3 is essential 3 grams per running meter is weight of the PIB to be applied and also avoid skips. There should not be any areas, where there is no primary seal and good surface wetting and flow during glass pressing. So, it should be nicely wet and 0.3 mm thickness,

and greater than 4 mm. So, this is very-very essential things for the primary seal. You can visually see you can control it.

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**3. IG Unit Pressing Operation**

- Pressing
- **PIB** = highly viscoelastic material. It flows under low shear rate/slow pressure build-up, but behaves elastic under high shear rate/fast pressure built-up.
- **Temperature**: the colder, the more 'elastic'; the hotter, the better it flows and wets out spacer and glass. Differences between summer & winter and Monday mornings (cold start-up) versus rest of the week
- **Monitor pressing operation**: speed/rate, pressure, displacement, ambient & operational temperatures

The slide also features logos for NPTEL and GLASS ACADEMY in the top right corner, and a video inset of a man in a checkered shirt speaking on the right side.

So, these are nothing like you cannot see, them when application you can see. So, second is pressing once you make the clean glass and apply it, PIB, and then you press it. You press the spacer to the glass and the PIB is viscoelastic. So, it, it shows under low shear rate, you know behaves elastic under high shear rate. So, if you pull it fast it will behave like a you know elastic, but if you pull it slow it will come out. Temperature so, again, you know the colder the more elastic or under hot air the better it flows.

So, what is between what is important to understand is when you are doing the application in the lower temperature or you have a control atmosphere where you do not know to monitor all these. If you have a winter or a summer then this will affect the application of the PIB and also the monitor pressing it has to be properly aligned. So, that you get a uniform gap around the perimeter and then press the other pane you know on the space.

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#### 4. Secondary Sealant

- Rigid seal reducing movements on primary seal
  - High modulus
  - Higher thickness, recommended 2nd seal thickness is 6mm. For structural IG edge a minimum 2nd seal thickness of 6mm is required
  - High elastic recovery reduces creep and will be an advantage
- Low volume increase under high humidity
- Low gas diffusion coefficient reduces gas loss ratio in case of leaking of primary barrier

**Why Si-Sealed IGU Outperform Organic Sealed IG:**

- Better mechanical properties: i.e. lower  $T^{\circ}C$  dependency of Young's modulus, elastic recovery
- Lower water pick-up (swelling) in high humidity micro-climates
- Si provide the best UV resistance and highest longevity for IGU. Only silicone can be used for structural IG



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So, secondary sealant; so, the minimum is 6 millimetre which has to be applied this is the one which is secondary sealant silicone here, it should be high modulus, and also for structural edge this is minimum 6 low volume increase under high humidity. So, you have to select a product which you know. Now it is always silicone so, you have to always silicone, silicone for the, secondary seal, and also as a combination they give the best, durability.

So, we are going to see, you know again, we have seen that, to you know bring it back with silicone you get the lower temperature, dependability better mechanical properties for the long-term very low water pick up. This is actually a water resistance material and best UV resistance. So, you get long-term durability.

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## ■ QA Testing for 2 part

Testing required every time the pump is started

- Butterfly test to determine mix is good ✓
- Snap time test to determine mix ratio is correct
- Adhesion test to determine time to achieve full adhesion – includes H-bar, but peel tests can also be done on glass & spacer frames
- Results should be recorded in a log book



$A+B$   
 $A:B$  (11:1 to 13:1)  
12:1

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So, what are the essential things for the DGU, when you receive the material you always look at the batch numbers and you always look at the shelf life the expiry. So, you have to have the material with minimum shelf life of say 2 to 3 months when you are actually starting to use a material. And then essentially, there is a condition which is mentioned as a storage temperature always store this material under 30 degree centigrade for both part A and part B.

And if it is not in use on a machine if you are going to keep it for the longer time you can remove and pack it is water air tight and then keep it in the stores. So, the test which are to be taken, can you know you have to conduct while applying the secondary seal is the butterfly test.

So, you are mixing two components A and B. So, the A and B have to have uniform mixing. There is a black and white component. So, when you mix it you should not have streaks of white or you know dark blacks. So, you should not have that you have a uniform colour mix snap time is to check the ratio between A and B. So, there are recommended ratio from the manufacturers which are generally you know, 11 is to 1 to 13 is to 1 by weight.

So, you can always be in a in the range to 11, 12 is to one by weight. Adhesion we have to check adhesion of a secondary seal to glass, as well as the spacer. So, there are certain test like peel test, glass butterfly adhesion test, in the H bar which has to be you know,

you have to conductors' part of the q a program.

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So, this is a picture showing you, you know, that test of the butterfly. So, once the machine is started, you remove you put the peel remove the air and then, you know apply start applying the, mix silicone on a paper and fold it and open it what you get is a uniform colour, mix. So, you do not see any streaks here. So, that mean this is a good quality, sealants which can be used for the application. So, if you do not have a good quality this is a bad quality which is rejected or even if you any some streaks that is rejected.

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So, what you need is this and second test is to check the ratio you take a small amount of mix silicone in a cup put a spatula when you initially pull it you will find a shrink. After sometime this will snap, the most of the times for many products the snap time is between 35 to 45 minutes. So, this can be slightly affected, because of the climatic conditions, but you anything in this range is really good. The peel adhesion test, H piece butterfly adhesion test these are again very-very important quality control check, we have to do prior, you know while we doing the application of a silicone, onto the DGU.

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**Structural Glazing and Insulating Glass Application and Quality Control**

**Adhesion and Cure Quality Control**

- **Peel Adhesion Test dry** is the recommended method to verify sealant adhesion to SG substrates. This test should be performed to substrates after each pump start-up and container change.
- **H-Piece Test** can be used in lieu of the peel test for a daily adhesion test. The H-Piece test should be performed for each container change to verify cure and strength of the sealant.
- **Butterfly Adhesion Test** (only valid for IG) can be used in lieu of the peel test or H-piece test to evaluate adhesion of sealant to



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So, you have a glass spacer you apply a small amount of silicone under the spacer by cleaning it and pull it same thing, you do it on the glass apply a small amount of silicone allow that cure after 24, hours pull it.

So, when you pull it the silicone should not leave the substrate and come out clean and the H piece is something like you make a joint, like a H if you take 2 panes of glass and then apply a silicone in the middle, and allow it to cure and pull this using a tensile stressing machine and you can see the failure should happen here not on not either on the bonding area.

The butterfly adhesion is a very normal test you take a glass two panes of glass, put a spacer around and then apply silicone on only one side after 24 hours you open it like a book. Essentially you will see that, how the silicone is bonding to both glasses under spacer.

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So, this is a picture showing the peel adhesion test, you can do it on; you have to do it on the glass you have to do it on the spacer after 24 hours you just pull it on what is essential you should not leave the substrate and come out clean this is called as good adhesion.

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### Butterfly Adhesion Test

1. Dow Corning Insulating Glass Silicone Sealants
2. Spacer system
3. Float glass scored then broken at midpoint

Elements to consider:

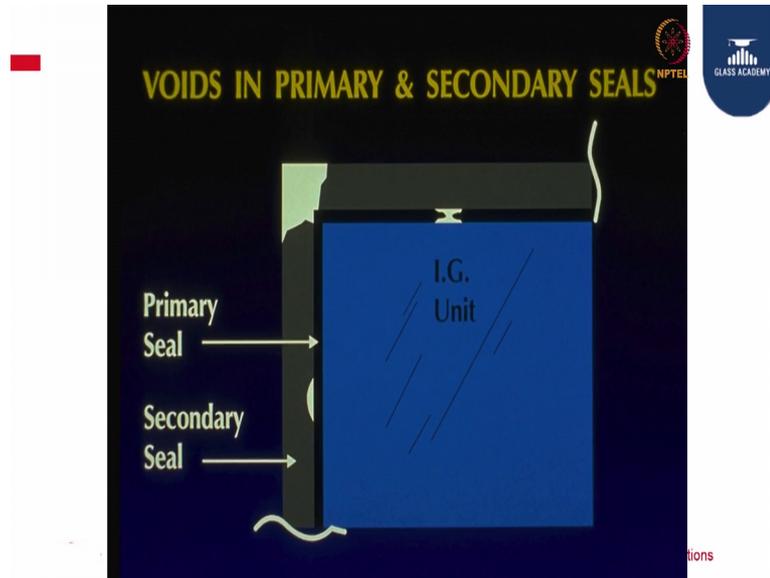
- Sealant free of voids and bubbles.
- Sealant homogeneity.
- Continuity of PIB application.
- Sealant adhesion to glass.

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This is the butterfly adhesion, you take this, one feet by one feet glass, put spacer around, either way you can do it you put a secondary sealant. Here, on one side or put a secondary seal on this side and then open it like a book; when you pull it and you can see

that the adhesion of silicone to spacer and to the glass it should not come out clean from both (Refer Time: 21:45) we should fill all primary and secondary seal throughout the perimeter of the DGU there should not be any gaps.

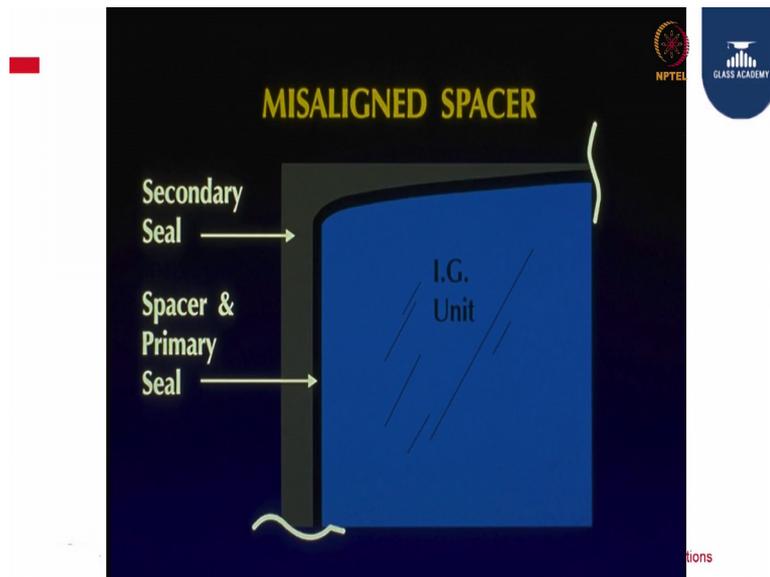
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There should not be any voids and the bend there should not be any discontinuity it should be a continuous application like this ok, and here full. And this is the misaligned spacer if it is spacer is misaligned you are going to have differential secondary seal bite which is not good for, taking the loads.

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### 5. IG Units – Transport and handling

- Curing conditions equal to production conditions (temperature, pressure)
- Curing time > 24 h for 2-component sealants, > 7 days for 1-component sealants (6mm)
- Transport only after complete curing, but minimum after 3 days
- Avoid height/pressure differences during transport
- Capillary Tubes vs Breather tubes



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Then, you have to pack them properly allow them to first cure you have to have a curing of 24 hours for two component and, depending upon the bite size 7 for one component. For a 6 millimetre by generally you need 6 to 7 days to cure for if it is a 1 component,

but most of you do not use 1 component you only use 2 components.

So, the recommendation is to keep it for a day and then pack it nicely you do not allow them to have differential loads between two panes even while, stacking if you are stacking vertically ensure that both the glasses are supported properly and there is no differential, load coming on the sealant when it is in uncured stage and avoid height pressure differences.

So, if you are doing an application on the, ground level sea level and then exporting it to a very altitude, you know when you are doing that you have to have breather tubes or capillary tubes to and you know untie them and then. So, there is no pressure difference which will cause a concave or a convex shape in the DGU. So, this is something which you need to understand depending upon the insulation sides height.

(Refer Slide Time: 23:32)

**Making a high quality IG Unit?**

**Glass**

- Smooth glass surface < 10um (avoid rough surfaces as sandblasted or enamelled)
- Remove glass coatings (up to half of butyle line), residuum may not affect adhesion of sealants, take care about adhesion on mechanically removed coating (as we know, bismut is critical)
- Clean/wash glass panes properly, no contamination may remain

**Spacer**

- Proper frame setting or frame extrusion
- Banded Frame, constant width, smooth butylisation area
- Desiccant filling, enough and not preloaded with moisture
- Clean/prime the spacer frame (if needed)

**Butylization**

- Semi automatic butylisation, minimum 3g/m for each butyle line
- Constant butyle bite > 4mm
- Constant butyle thickness > 0.3mm (measuring via unit thickness)
- Connectors sufficient butylised, also welded connections must be smooth and tight
- Gas fill holes (if any) must be properly closed with butyle
- Frame setting, constant distance from glass edge
- Visual control of butylisation, homogenous pressing and wetting of glass surface, no visible break of butyle line allowed

**Pressing**

- Inline pressing (in gas fill chamber))
- pressing should be slow and smooth, warm up would be good to get optimum flow of butyle to the surface (wetting)
- best parameters of individual IG line must be found by trial and error (looking on butylisation quality and butyle thickness)
- either pressure or distance must be controlled to obtain a homogenous butyle thickness and to avoid to much pressing
- After pressing, check planity of IG unit, no overpressure (blown up) allowed

**2<sup>nd</sup> seal application**

- Secondary sealant with ultra high modulus and elastic recovery at all temperatures (DC 3362 HD)
- Automatic, immediately after glass pressing
- homogenous mixing, correct mixing ratio, air free application
- More thickness of 2nd seal gives more mechanical strength to the IG edge and reduces movement within primary seal, recommended 4-6mm minimum
- Curing and adhesion control tests on all substrates (glass with removed coating, spacer)

NPTEL GLASS ACADEMY

1981

tions

So, to summarize what is important to make a high quality I.G unit glass you need to have a smooth glass surface no rough surfaces no coarse coatings. So, ensure that, you have a good rating of silicone on both primary and secondary seal and also, remove the you know whatever the, high-performance glass coating needs to be removed properly you removed that. And also you check with the manufacturer on how much it has to be removed clean and wash the glass panels properly use the proper water quality to clean them. State spacer stted properly, when the frame have the constant width around and in position them properly you, you know apply butyl, with the smooth butyl for the,

required width and the thickness.

Fill enough desiccant and it should be fresh the desiccant also should be tested for its a temperature raise as well as a moisture absorption clean and prime the spacer if it is required some of the spacers would need some cleaning and priming.

So, on the butylization maintain the machine, these are essential thing we talk talked about three grams per running meter greater than 4 millimetre of width and 0.3 millimetre thickness. So, these are all important for you to give you a good tight primary seal, connectors also properly butylized and if there are any holes which are gas filled that has to be also plugged properly, and also frame setting you have to set the frame properly.

So, that you have constant edge throughout the perimeter you see visually and then if you see any breakages redo it, pressing inline pressing you can do inline pressing you can do an inline gas filling, should be smooth and the easy should not be very, rough the and also, it should not. So, much compressor the material like a primary seal to come, come inside the DGU your, and again homo.

So, when you press you get that that homogeneity around the perimeter not too much of a thick and, thin butyl, no pressure or grown up allowed after pressing secondary seal which is again a silicone sealant a silicone sealant is ultrahigh modulus you have to use which has got good elastic recovery at all temperatures.

So, products are like 3362 or 982 is from you know what is generally used automatic immediately you know, you can do an automatic application or you do a manual application around the perimeter. Check the mixing check the butterfly test check snap time do peel adhesion test, and also designed the secondary seal depending upon the loads which is coming onto that 6 millimetre is minimum, generally we do not recommend 4 for any of our commercial glazing applications.

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**Insulating Glass  
Application and Quality Control – Testing summary**

	After each pump start-up	After each container change	After each substrate change	Diagnostic investigation
Glass test	Required	Required	-	Required
Butterfly test	Alternate to Glass test	Alternate to Glass test	-	Required
Snap Time test	Required	Required	-	Required
Mixing ratio test	Not required	Not required	Not required	Required
Peel Adhesion test dry	Required	Required	Required	-
H-Piece test	Alternate to peel test	Required	Alternate to peel test	-
Butterfly Adhesion test	Alternate to H-Piece test	Alternate to H-Piece test	Alternate to H-Piece test	-

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So, what you need to do is whatever test you do you document them you maintain, records for a glass test which is like a either you do the butterfly on the glass or you can do it on the paper, snap time mixing ratio is for the pump to check the quality of the pump, delivery of materials. So, this is done randomly.

So, you do not need to do it every time, but is required as a diagnostic test. You can do it once in a month peel adhesion test which is very essential on glass as well as on the spacer you can do h piece or peel you know peel adhesion, butterfly adhesion is another way of doing the, H piece test you can do this and this you can do it, intermediately.

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### Application equipment

#### 1 Component

- Hand held equipment for 310 or 600 ml. Hand, battery or air powered
- Pail pumps for 20/200 l pails or drums. Air powered



#### 2 Component

- 2 component meter mix Machines. Air powered.

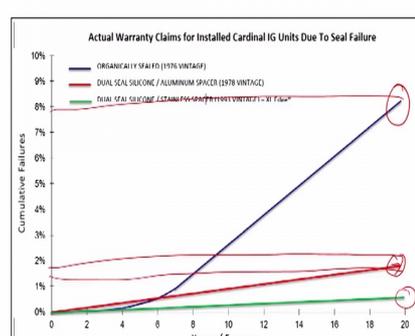


Consumer Solutions

Application equipment you need to have a good dispenser from a reputed manufacturer who gives you service or you can have your own service engineers maintaining this equipment and checking the edge seal checking the air pressure indicators the walls and cleaning the host the mixer properly.

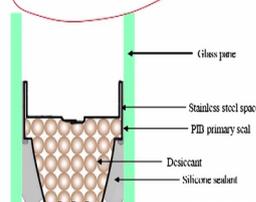
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### Sustainability and Life Cycle Costing – Increased Longevity of Silicon Sealed Units



Years of Exposure	ORGANICALLY SEALED (1976 VINTAGE)	DUAL SEAL SILICONE / ALUMINUM SPACER (1978 VINTAGE)	DUAL SEAL SILICONE / STAINLESS STEEL SPACER (1993 VINTAGE)
0	0%	0%	0%
2	~0.5%	~0.2%	~0.1%
4	~1%	~0.3%	~0.1%
8	~2%	~0.5%	~0.1%
10	~4%	~0.6%	~0.1%
12	~6%	~0.7%	~0.1%
14	~8%	~0.8%	~0.1%
16	~10%	~0.9%	~0.1%
18	~12%	~1%	~0.1%
20	~15%	~1.2%	~0.1%

- 1976: aluminum spacer, PIB/polysulfide
- 1978: aluminum spacer, PIB/silicone
- 1993: stainless steel spacer, PIB/silicone, proprietary design



<http://www.cardinalcorp.com/products/insulating-glass/xl-edge/>

Consumer Solutions

So, that you do not have time to time breakdowns. So, this is, interesting case I wanted to show it which is available in cardinal; in the cardinal started making the DGU in 1976 with aluminium spacer, PIB and polysulfide. They started with polysulfide they had a

failure rate of up to say 8 percent, you know when the life of the DGU was moving from 0 to 20 years they give 20 years, essentially, because their process is so, nicely manage they are able to give service life of a 20 years for the DGU.

Then in 1978 they change to silicone and you can see that, it immediately you know a drop from 8 percent what you see here to just less than 2 percent even less than 2 percent 1.5. So, this was one of the significant things they got it and when they move to stainless steel PIB silicone which is their own proprietary design it got further load on to 0.5 or even lower than that.

So, what is it choice choosing the material combination and also doing a good quality control in the whole exercise you can reduce the defect what happens on the DGU for a 20 years life. You can you can see that.

(Refer Slide Time: 28:36)

**Manufacturing Practice for Durability (David Cooper - Guardian)**  
dcooper@guardian.com

- **Quality**
  - Get everyone involved in quality
  - Perform QC checks regularly
  - Record lot numbers
  - Read and understand the product MSDS
  - Use appropriate safety gear (gloves, arm guards, eye protection, etc.)
  - Store sealants in a clean, warm, dry environment
  - Control application temperatures, humidity
  - Purge sealant if not used for a period of time
  - Perform regular, scheduled pump maintenance
  - Edge delete coated glass as required
  - Understand physical properties, strengths and weaknesses of your particular sealant choice
  - Follow sealant manufacturers' recommendations for compatibility, QC tests and application procedures of the sealant.

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So, as per them what they do is these are the important things they always talk about is get everyone involved in the, in the process of making a good DGU. Do regular quality checks, record maintain records properly; understand the products, understand the behaviour use proper safety PPES while using the materials store the material properly apply them in a good atmosphere, and also purge a sealant periodically.

So, that you do not get the cured ones, perform regular pump maintenance edge delete coated glass as per the manufacturer's recommendation, understand the total quality

control application procedures. Things to avoid do not lubricate around I.G sealant non- especially, non-silicone-based, silicone-based sealants which are like different cure I will show you this and also the non-silicone-based, stack uncured I.G units at an angle.

(Refer Slide Time: 29:15)

**Things to avoid (David Cooper – Guardian dcooper@guardian.com)**

- Use of lubricants around IG sealants, especially silicone-based sealants
- Stack uncured IG units at an angle
- Skimp on sealant application
- Glaze or ship IG before the sealant is sufficiently cured
- Smoke, eat, or drink around IG sealants
- Use hand cream or lotion in contact with sealants
- Use expired or questionable material
- Allow gaps in primary or structural sealant coverage
- Drag spacer with sealant across floor.

The slide also features the NPTEL logo, the Glass Academy logo, and a photograph of David Cooper, a man with glasses wearing a checkered shirt, who is speaking.

So, you have to properly keep them at an angle. So, that they do not, have you known, impart loads you know skimp on sealant application how you finish it do not scoop them out glaze do not glaze you know, do not stack them on a, on an angle you have to stack them vertically the both the pan should be supported.

So. you do not use, anything like in lubricants around the I.G sealants you do not skimp on the sealant, while application, you do not glaze or ship them before it is cure do not eat smoke eat around, the area where you manufacture. Do not use lotions, you know cream, do not use expired materials do not allow gaps or do not drag spacer across the floor. So, this is something which is essentially say, that do not do it.

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## EN 1279 Part 2 - Requirements



**4 Requirements**

**4.1 Moisture penetration index**

Insulating glass units shall fulfil their functions during an economically reasonable working life. Therefore the following values are verified on test specimens submitted to the climate test described in this Part of the standard:

The average moisture penetration index  $I_{av}$  over the five test specimen shall not exceed 0,20.

Although breakage of the glass does not constitute failure, the average moisture penetration index  $I_{av}$  shall be the average over not less than, and no more than, five units. Spare units shall be used instead of the broken test specimens.

The unit with the highest moisture penetration index shall have an index value  $I$  not exceeding 0,25.

15 test units  $I_{1,2,3,4,5} < 25\%$  and  $I_{av} < 20\%$

$$I = 100 \frac{T_f - T_{i,pm}}{T_{e,pm} - T_{i,pm}} \text{ in \%}$$

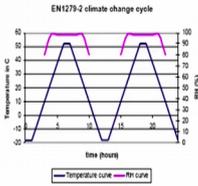
Molecular sieve moisture content:  
 $T_f$ : final,  $T_i$ : initial,  $T_e$ : moisture absorption capacity  
 Determination: gravimetric (molecular sieve), Karl-Fischer  
 Titration (desiccant incorporated into seal)

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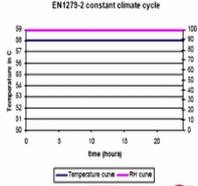
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## EN 1279 Part 2 – Test Method (Overview)





EN1279-2 climate change cycle



EN1279-2 constant climate cycle

Changing Climate Test: 56 cycles of 12 hours (+18° C to +53° C) = 4 weeks  
 Constant Climate Test: 1176 hours = 7 weeks at 58° C and >95% r.h.

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So, just to quickly take you through the standard is, there are two standard which talks about the long term pressing of, DGU, E N 1279 and ASTM. So, in 1279 what they talk about is doing the climatic test at 12 hours between a temperature minus 18 to 53 for 4 weeks and 7 weeks at constant temperature with 95 percent r h.

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**ASTM E2188 Durability Test Protocol**

ASTM E2188-10

- High Humidity (140° F (60° C) and 95% Relative Humidity) = 2 Weeks
- Weathering Chamber (UV Radiation, Temperature Variation, Water Mist) = 9 Weeks
- High Humidity = 4 Weeks

Before testing and after each phase, specimens are evaluated for

- Frost Point (less than -90° F (-68° C) is an acceptable result)
- Argon Retention (must average greater than 80% argon concentration)

Logos: NPTEL, GLASS ACADEMY

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The slide contains handwritten red annotations: a red box around the title, red circles around the '2 Weeks', '9 Weeks', and '4 Weeks' durations, and red lines connecting the phases and evaluation points.

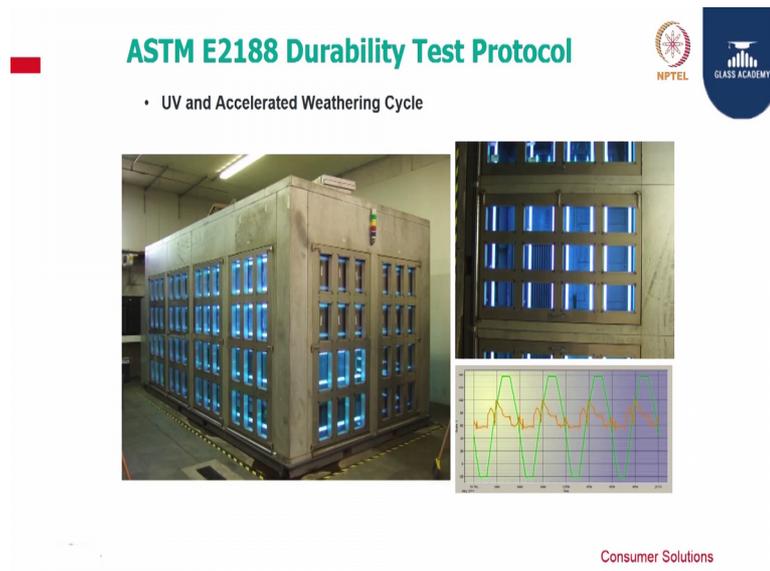
So, there is a temperature change they do it for four weeks or minus to plus and at a constant temperature. They do it at a high humidity and check the durability of the DGU union whereas, the ASTM E188, you know talks about durability in high humidity 60 degree centigrade at 95 percentage for 2 weeks, but they put this into weathering they ask you to put it in UV chamber where it is subjected to the actual weathering conditions with temperature variation water mist and UV for nine weeks and again the high humidity for four weeks.

So, what is important here is a climate like hours a UV is a very essential part though En is a very good standard though it does not cover anything on UV. So, what is essential is we need on up to the standards which also has a test method closer to hours.

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### ASTM E2188 Durability Test Protocol

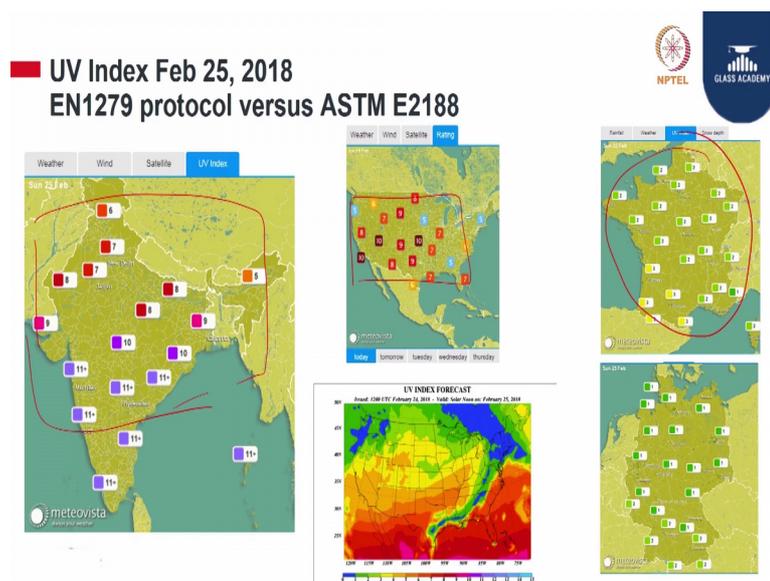
- UV and Accelerated Weathering Cycle



The slide features the NPTEL and GLASS ACADEMY logos in the top right corner. The main content includes a photograph of a large industrial UV weathering chamber with multiple viewing windows, a close-up of the chamber's interior showing a grid of test specimens, and a line graph showing a fluctuating data series over time. The text 'Consumer Solutions' is located at the bottom right of the slide.

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### UV Index Feb 25, 2018 EN1279 protocol versus ASTM E2188



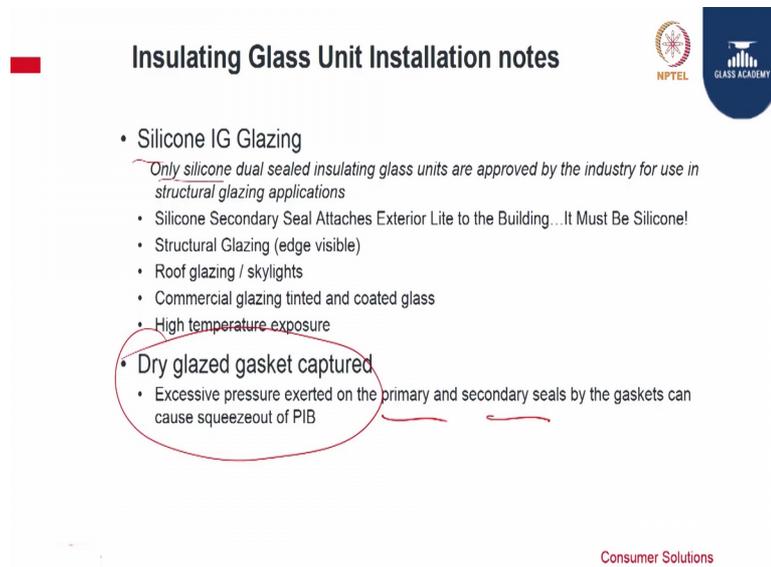
The slide displays the NPTEL and GLASS ACADEMY logos in the top right corner. It contains several maps and a forecast chart. On the left, a map of India shows UV index values ranging from 7 to 11+ across different regions. In the center, a map of the United States shows UV index values from 1 to 10. On the right, a map of Europe shows UV index values from 1 to 4. Below the US map is a 'UV INDEX FORECAST' chart for the period from 0200 to 2200 hours. The text 'Consumer Solutions' is located at the bottom right of the slide.

So, the ASTM seems to be closer. So, this is in UV chamber wherein they put the DGU, tested for you know 9 weeks. So, why am I talking about this is if you look at a country like India, we have a lot of zones and you know areas where we have UVs.

It is not that, we do not have UVs so, we have UV. So, UV is very-very important with the same thing in US you will have UV around, but if you look at Europe they do not have much of UV. For them it is not an essential thing whereas, for as this is very-very important this available in Google you can you know Google it out and, check this last, I

am going to just summarize.

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**Insulating Glass Unit Installation notes**

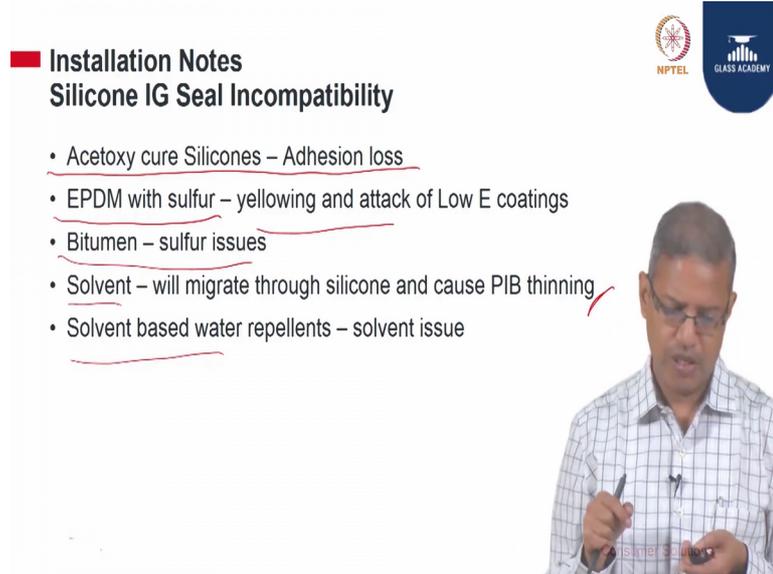
- Silicone IG Glazing
  - Only silicone dual sealed insulating glass units are approved by the industry for use in structural glazing applications
  - Silicone Secondary Seal Attaches Exterior Lite to the Building... It Must Be Silicone!
  - Structural Glazing (edge visible)
  - Roof glazing / skylights
  - Commercial glazing tinted and coated glass
  - High temperature exposure
- Dry glazed gasket captured
  - Excessive pressure exerted on the primary and secondary seals by the gaskets can cause squeezeout of PIB

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So, only silicone dual sealed insulating glass units are approved by the industry for use in glazing applications we cannot have an organic seal it on a commercial glazing where you have a degradation of the secondary seal which happens. Silicone seal attaches an exterior light of, the light to the interior and also the unit to the building structural glazing the edges are visible in the roof glazing and skylights.

Again, you can do it with completely silicone you can use, in the commercial glazing different types of glasses and all of them are subjected to temperatures depending upon the climatic, conditions what you see here. Dry gaskets excessive pressure exerted while fixing the dry system on the primary and secondary seals can squeeze out also PIB just be careful about when you are using a dry system ensure that the pressure is normally maintained properly.

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**Installation Notes**  
**Silicone IG Seal Incompatibility**

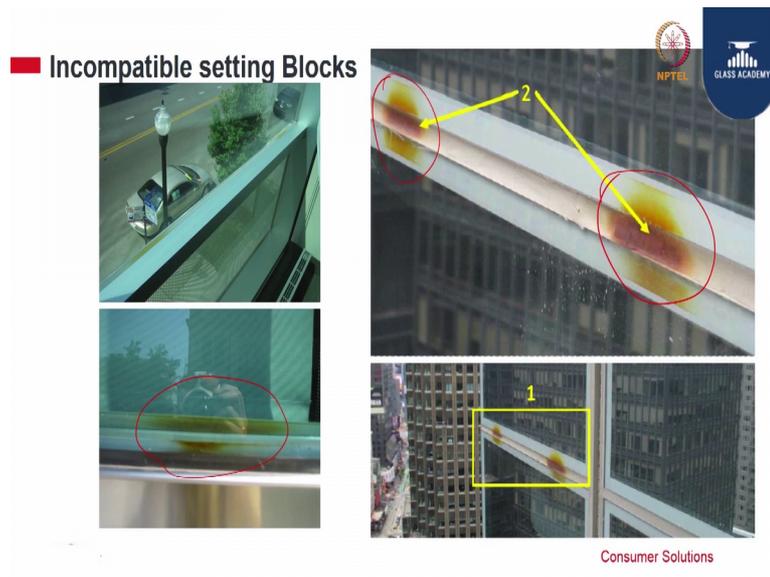
- Acetoxy cure Silicones – Adhesion loss
- EPDM with sulfur – yellowing and attack of Low E coatings
- Bitumen – sulfur issues
- Solvent – will migrate through silicone and cause PIB thinning
- Solvent based water repellents – solvent issue

The slide also features the NPTEL logo and the Glass Academy logo in the top right corner. A presenter, a man in a checkered shirt and glasses, is visible in the bottom right corner of the slide frame, holding a pen and a small object.

And also, what is also important is when you are using the DGU or which are made with the neutral cure alkoxy systems do not use any acetoxy cure silicones in contact with the secondary seal of the DGU or do not use this as a sealant for making the DGU. Do not use anything with the EPDM with sulphur, because this can attack the coating, of the glass as well as the secondary seal.

Do not use any between this sealant in contact with the DGU secondary seals do not use any solvents which will migrate through the silicone as I told you as I told you there are some moisture vapour permission reads silicone can allow and it can also cause the PIB thinning do not use any solvent based water repellents around the, you know perimeter of the DGU.

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So, also the incompatible setting blocks like if use a EPDM with lot of plasticisers of the sulphur in it can cause a colour change, and make it incompatible. So, you can see them here so, these are all the essentially the effect of, the setting block not being compatible with the secondary seal of the DGU and these are the PIBs affected by the solvents somebody has put a high chemical around the perimeter while cleaning the or you know while, applying that in a wooden frame or something.

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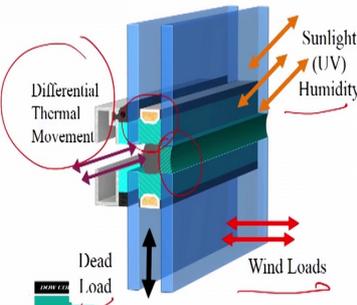
■ **PIB flow**



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■ **Structural Silicone Glazing (SSG)  
The Flexible Rubber Anchor**



- Load bearing bonding between glass and supporting metal frame using structural silicone sealant results in continuous thermal barrier and excellent air and water intrusion performance

- Bonding must be dimensioned according to (thermal, live & dead) load requirements
- SSG sealant carries loads and compensates movements
- Higher performance requirements on IG edge seal regarding UV- and heat-resistance
- IG edge seal must fulfill live and dead load-bearing function

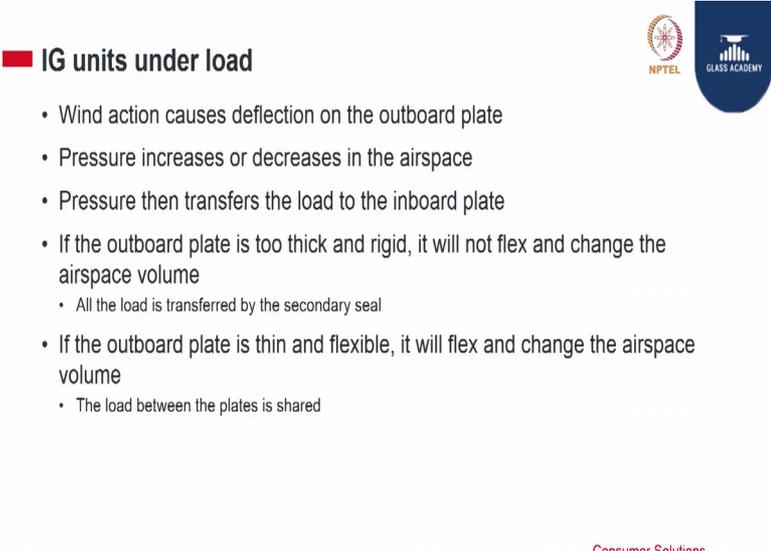
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You can see the primary seal running down around the perimeters here again a, wrong sealant is being used which is coming in contact with the PIB. So, last what is important is you have structural silicone holding the glass the entire DGU to the frame you have secondary seal inside the DGU which is holding two panes of glasses together you have weather seals.

They are subjected to wind loads, they are subjected to UV, they are subjected to sometimes dead load and they are also subjected to differential thermal movement

silicone provides, the good flexible anchor for the long term. So, that is the right choice of the material, but what we, you need to understand is you need to really understand that, there are many parameters which are involved while making the DGU.

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**IG units under load**

- Wind action causes deflection on the outboard plate
- Pressure increases or decreases in the airspace
- Pressure then transfers the load to the inboard plate
- If the outboard plate is too thick and rigid, it will not flex and change the airspace volume
  - All the load is transferred by the secondary seal
- If the outboard plate is thin and flexible, it will flex and change the airspace volume
  - The load between the plates is shared

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**Cold Bent Insulating Glass**  
**Motivation and Scope of Research**

InterActive Corporation Headquarters, New York, 2006



Nine years and counting...

NPTEL GLASS ACADEMY

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So, this is what I had today to share it with you, now there are lot of new trends coming in people are coming with cold bent glasses in DGU, these are all new approaches there are lot of stresses which will happen on the secondary seal. So, essentially, we need to

evolve with an industry keeping in mind that what essentially, we need is a very-very clear DGU at the end of the day which has a good long-term durability.

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**■ Literature and Standards**

- ASTM E1288, 2189, 2190
- ASTM C1249
- ASTM C1369
- ASTM C1087
- EN 1279 parts 1-5
- IGMA Quality Management System for the fabrication of IG units.
- IGMA NA Glazing Guidelines
- GPD Glassfiles

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**■ IG Durability: The concept is Clear**



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### **Summary:**

By the end of this video, you have learnt about the:

- Dry glaze curtain wall
- Structural silicone glazing curtain wall
- Making of IG units
- Performance Influencing factors of IG unit
  - Spacer
  - PIB-Application
  - Pressing Operation
  - Secondary sealant
  - Transport and handling
- Application and Quality Control
- Manufacturing practice for durability
- ASYM E2188 Durability protocol
- Insulation Glass units Installation notes

These are the some of the standards which you can refer and this will give you lot of ideas about the tests which needs to be involved when making the good DGU. So, last, but not the least the concept is clear, we do not want the DGU to be fogging like this and we saw what needs to be done to get to that.