Challenges of Bent Insulating Glass

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Keywords

1=bent insulating glass 2= flexible spacer 3= sealant/sealing 4=handling 5=application

Insulated Glass Units

Flexible and creative design continues to place every increasing demand for higher performance glazing without sacrificing style. Many of today's building designs (both exterior and interior) incorporate the use of insulating bent glass design. It is well known that the fabrication of bent glass and bent insulating glass present significant challenges. The market has learned much over the last 10 years, and newer technologies are making it easier to get more creative in design without sacrificing the quality and integrity of the bent insulating glass. This paper will outline these challenges and present several ways to minimize the pitfalls of design, fabrication, and of insulating bent glass using case studies from around the world.

What is the big challenge? New regulatory drivers and energy rating programs continue to raise the bar for the fenestration industry around the world. The traditional flat glass market has met this challenge by offering solutions in the form of warm edge spacers and high performance glass coatings to meet the energy codes. Bent glass has long been used in commercial and residential design to help building owners and developers create unique and eye catching façade design. The process of bending glass continues to be as much an art as it is a science. The shape and style of monolithic bent glass is almost limitless. Typical types of bends are shown in Figure 1.

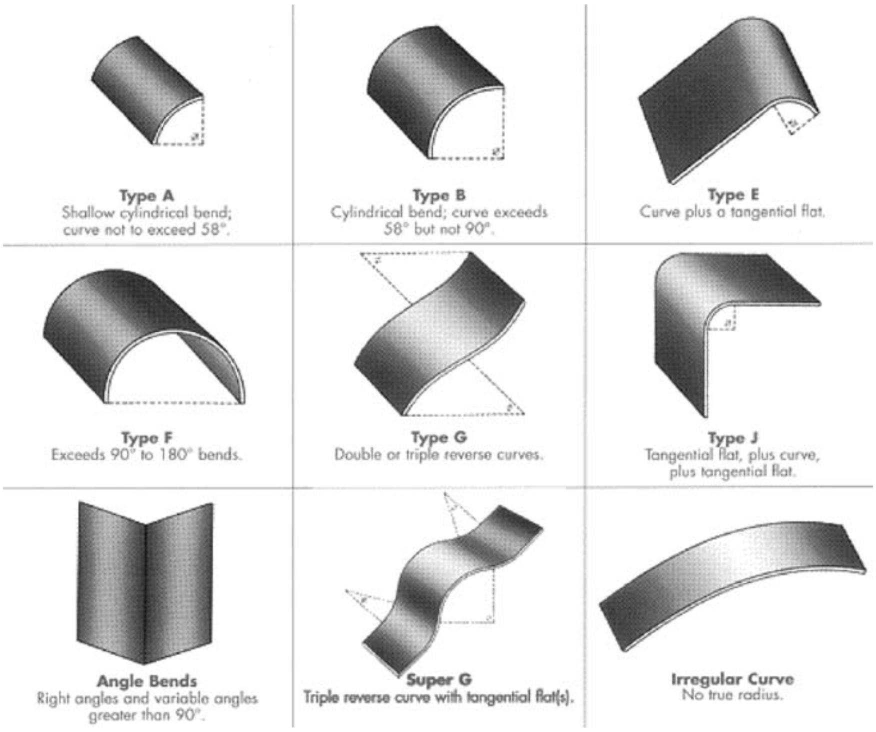

Figure 1 (Courtesy on Standard Bent Glass Corporation website)

The requirement for improved thermal efficiency and energy saving creates a dimensional challenge for bent glass that the flat glass market has never experienced. Bent insulating glass requires that the fabricator now bend two, three and potentially multiple different flat pieces of glass with different surface coatings to a parallel shape that will be separated with a fixed width air spacer (Figure 2).. Here in lies the greatest challenge. How can we minimize the irregularity of a process that lends itself toward inherent variation and potential flaws? We will explore some of the options that are available to the market today.

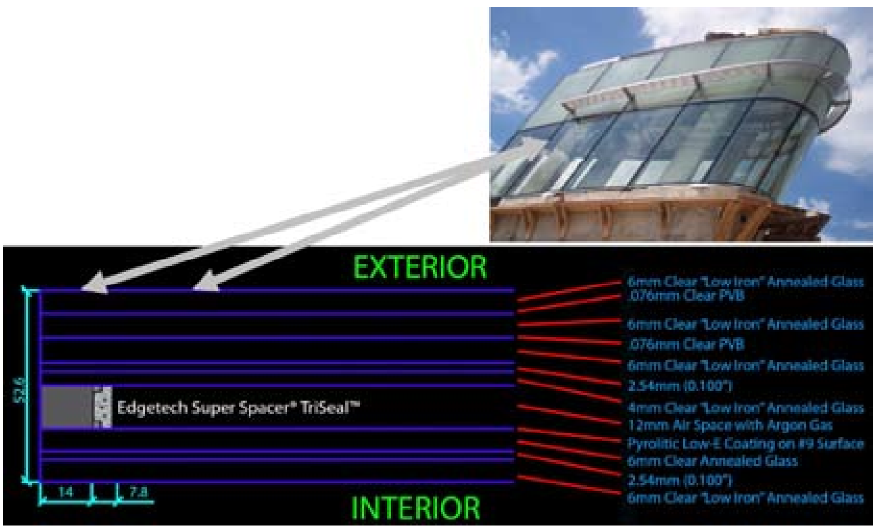

Figure 2

New technologies and processes available today allow architect to design with true curved or bent glass without

Figure 3

Figure 4

Figure 5

sacrificing on the performance that is available for flat glass.

Project Examples:

The Challenge: Long term durability of bent glass IG assembly

Traditional flat glass insulating glass has been tested to many standards around the world. Until recently fabricators of IG in Europe had to test to a different durability standard for each country that the IG was sold into. With the collective work of many in the industry we have seen the consolidation of the durability testing requirement into one norm (EN 1279). The purpose of this testing is to validate the manufacturing processes of the fabricator to consistently and repeat ably make units that will satisfy the standard. The North American market has also implemented numerous standards for testing durability over the years including the ASTM E 773/774 and CGSB 12.8. The latest standard is ASTM E 2190 which has harmonized the US and Canadian testing requirement. Again, the end goal is to prescribe a test that will give the fabricator the confidence (if they pass the test) that they are producing a durable IG unit.

Edge seal design plays a significant role in determining the long-term durability of the IG. It is important to remember that simply passing a durability test is not a guarantee that the selected system is the best choice for consistently constructing a durable seal. Manufacturing friendly systems that reduce handling steps while providing the necessary flexibility and energy saving characteristics are more likely to provide the repeat ably long term durability that is desired.

It is well known that the edge seals on bent glass are typically subjected to even greater and more dynamic stresses than traditional flat glass IG. Because of this fact fabricators and design professional should be more

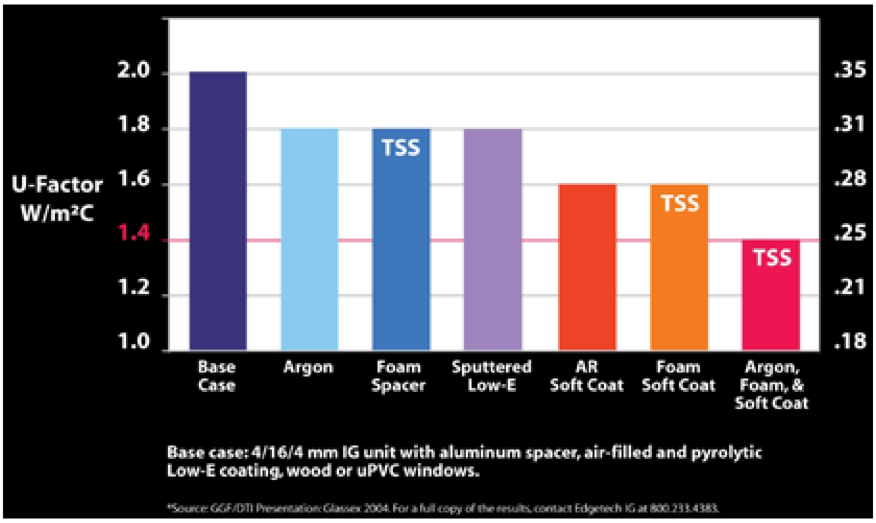

Figure 6

diligent about specifying and using an appropriate edge seal. Proper system design and specification are necessary to reduce the cost associated with failed bent glass IG units.

Durability of seals for bent glass can also impact the selection process for other components of the bent glass or flat glass. Trade offs can be made with glass coatings, gas filling and spacer to achieve the desired energy savings related to the façade.

The chart below (Figure 6) outlines some of the available options for achieving lower U Factors. Using a base case IG construction of rigid metal spacer, air filled and pyrolytic low e glass in a PVC or clad wood frame we can achieve a 2.0 W/m2 C U- factor.

To reduce this value by 0.2 using the glazing technologies, we can change out one of the three components.

1. Replace the air with Argon gas
2. * Replace the rigid spacer bar with flexible foam spacer
3. Replace the pyrolytic low e with Sputter coated low e

Each selection has a consequence:

1. Argon filling improves the thermal efficiency of the IG but adds expense and process steps. Consumers still question the long term retention of argon in units. You cannot see it, smell it, taste it or feel it so how can we be sure it stayed inside the IG?
2. * Flexible foam spacers reduce manufacturing steps and increase thermal efficiencies with proven durability track record. It is possible to visually identify when this high performance spacer has been used in an IG.
3. Sputter coated low e improve thermal efficiency of the IG but they are more susceptible to scratches and handling damage.

To reduce this value by 0.4 from the base case using the glazing technologies, we can change out two of the 3 components.

4. Replace the air with Argon gas and replace the pyrolytic coating with a sputter coating
5. *Replace the rigid spacer bar with flex-

ible foam spacer (warm edge) and replace the pyrolytic coating with a sputter coated low e

Again each selection has a similar consequence.

4. Replacing the air with argon still creates questions by the consumer and the sputter coating has to be handled more carefully to avoid coating damage.
5. *Flexible foam spacers reduce manufacturing steps and increase thermal efficiencies with proven durability track record. Sputter coated low e improve thermal efficiency of the IG but they are more susceptible to scratches and handling damage

With each of the options listed you will achieve the desired result of lowering the U Factor. What should also become obvious is that substitutions of some components have far fewer negative cost and manufacturing implications than others.

The options with the * indicate the selection that offer the maximum efficiency and lowest potential for return due to manufacturing defects.

The Challenge: Choosing the proper IG spacer for the bent glass IG assembly

Spacer selection can also play a significant role in the overall thermal performance of the IG. Globally we continue to see the market embracing warm edge spacer designs to improve the energy efficiency of facades. Not all warm edge spacers provide the same level of thermal or manufacturing efficiencies. They also have varying levels of durability/sustainability especially when used in high stress applications such as bent glass. We will explore this in more detail weighing in on the pros and cons as it relates to bent glass. These principles will also apply for flat IG.

There are a wide variety of rigid and flexible spacers for insulating glass available on the market today. As the demand for high performance glazing increased we have seen a shift to less conductive spacer.

The rigid spacer design (even the thermally improved designs) are generally less desirable for constructing bent glass because of the propensity to kink or buckle during the bending process (Figures 7-8). They create inconsistencies for sealant application and are very time consuming to bend accurately.

For this reason we will focus on the advantages of the flexible spacer systems available on the market which are not susceptible to these problems (Figure 9-10).

When selecting flexible spacer for bent insulating glass it is important to consider the glazing application. Flexible silicone foam spacers for

Figure 7

Rigid Spacer bending issues

Figure 8

Flexible spacer bent without kinking

example have specific products for different glazing and sealant types.

Fabrication Considerations

The production of insulating bent/curved glass requires different production procedures than IG production with flat glass. Details concerning spacer fabrication, spacer application, sealant type, sealant depth, etc. are specific to the spacer/sealant system being used and are, therefore, not addressed here. Fabrication and application requirements specific to individual products should be at the direction of the respective product manufacturer. Additionally, method of IG unit installation concerning captured versus structural glazing must be considered.

1.1 Choose the proper insulating glass spacer and sealant system:

- Captured glazing systems are retained within the fenestration framing system and, therefore, may not require structural sealant systems.
- Non-captured, structural glazing systems are attached to the fenestration framing system with structural sealants. The outboard lite of the insulating glass unit lacks mechanical connection to the framing system and, therefore, a structural IG sealant is necessary to maintain IG unit integrity.
- Not all spacer systems are compatible with all sealant systems and the type of glazing system must be taken into consideration.
- Sealant selection may be outlined or defined by the Architect or specification and not at the discretion of the IG fabricator. Spacer and sealant compatibility issues must be properly communicated to the specifying authority.

1.2 Benefits and limitations of using flexible spacer with curved glass.

- Flexible spacers are easily formed to follow contours in curved or bent IG.
- There should be no more than 1mm

Figure 9

per lineal meter of non-parallel glass for matching purposes.

- Caution should be taken on IG units with large airspaces (> 12 mm) that the spacer does not lean during or after the matching process. Glass matching techniques become more important with larger airspaces.

1.3 IG production phases

1.3.1 Glass Preparation.

- Due to the complexities of bent glass surface characteristics it is typically necessary to clean the glass lites by hand prior to IG unit assembly.
- Particular care must be taken to not damage surface coatings on the glass surface(s).

Figure 10

1.3.2 Application of spacer

- To assure proper orientation and adhesion of a flexible spacer to the glass lite surfaces, it is best practice to apply the spacer to the surface having a convex curvature.
- For units having multiple, reversing curvatures, the spacer should be applied to the lite having the smallest convex radii.

Figure 11

Figure 12

Figure 13

Figure 14

1.3.3 Glass matching

- Unlike standard practice for flat glass, it is best to match the curved glass at one end of the unit and roll it to the other end. Curved glass is much too difficult to match all at once. In many cases it is impractical to lie the lite to which the spacer is applied in a horizontal orientation. In these cases it may be necessary for glass matching and spacer application to be performed in a vertical orientation.
- During the oven bending process the glass corners are the last to reach the desired temperature in the mold. Corners may not, therefore, be as parallel to the matching lite as are the remaining glass lite surfaces of the IG unit. To compensate for potential sealant voids, extra PIB in the form of PIB rope may be added to fill the gaps as the corners.
- Much of the corner sag can be predetermined based on the test/practice units that will be made prior to production.

1.3.4 Unit compression

- As machine pressing of bent IG is not typically possible, it is common to use "C" clamps around the perimeter of the unit to compress and wet-out the spacer and sealant (Figure 20). Care must be taken to protect glass surfaces to avoid scratches or other damage.
- An alternative method of compression utilizes a hand roller system guided around the perimeter of the unit to gain this wet-out (Figure 21).

1.3.5 Gas filling

- Care must be taken for proper placement of filling probes and control of flow rate to ensure an adequate fill of complex shapes and efficient removal of air from the glazing space.

Figure 15

Figure 16

- With the exception of taking more time to fill larger units, there are no special practices associated with gas filling. There may be a need to decompress the units if overfilled for unit deflection uniformity.

1.3.6 Sealing the units

- Based on unit size, weight, and configuration, it may be necessary to apply secondary sealant in a vertical orientation.
- In the vertical position, wooden or comparable material blocks may be used to support the glass from the floor. The unit would simply be slid or shifted when reaching the support areas to seal those locations. The unit should still be sealed in its entirety at the same time.
- The final quality aspects of the edge seal are no different than that with flat glass insulating unit.

1.3.7 Handling of newly made units

- Both lites of the IG unit shall remain supported on wooden or comparable material blocks while the secondary

Figure 17

sealant cures sufficiently for the IG unit to be handled. Glass handling devices such as vacuum cups, straps, etc. are used to transport the assembled IG unit as appropriate.

Conclusions:

The complexity and the increased difficulty of manufacturing bent insulation glass can not be completely eliminated, but with proper selection of materials and process these manufacturing challenges can be minimize. The fenestration industry has made significant advances over the years with high performance coatings, spacer material, framing and other enhancements. Commercial architects now have the flexibility – literally – to get creative with their building designs and energy savings. The advent of improved flexible warm edge technology brought about a new world of possibilities for using bent insulating glass and made creative day lighting possible without sacrificing the structural integrity and the energy efficiency of the building envelope.

Fabricators around the world can utilize these technologies to provide the architectural market with improved energy saving glass at a higher quality level without restricting the creativity of the designer.