

OPTICAL DISTORTION IN GLASS

OVERVIEW

The unique benefits of glass products such as high energy savings, beauty, durability, and visual transparency - make a difference in the types and styles of insulating glass units (IGUs) used in the exterior walls of today's residential and commercial buildings.

While much has been written about the improved energy performance properties of IGUs, there is little published on the distinct optical phenomenon that is inherent in all insulating glass units: reflective image distortion.

All industries involved in construction have experienced image reflectance when using glass. Most owners and architects have learned to consider the “non-linearity of reflective images” as a positive design feature. This document will provide background information to explain the causes of reflective image distortion to give context to our approach.

REFLECTIVE IMAGE DISTORTION

There are many reasons that distortion occurs in monolithic and insulating glass. Distortion in monolithic glass can be caused by glazing pressure around the periphery of the glass, wind-loads, and the heat treatment process.

For insulating glass, distortion can be caused by changes in temperature, changes in elevation from where the IGUs were fabricated, changes in barometric pressure, wind-loads, glazing pressure around the periphery of the glass and the heat treatment process used for heat-strengthened and tempered glasses.

Distortion is very subjective, and the degree of distortion can change due to environmental conditions as listed above. When dealing with IGUs, both the glasses are in constant bending movement resulting in multi-directional scattering of the image reflection and pronounced distortion. Such is an undefinable optical behavior that is inherent in all IGUs.

CONTRIBUTING FACTORS

Environmental pressure and temperature

A rise in barometric pressure and a drop in temperature causes concavity, where the glass bends towards the middle of the gas filled space between panes, while a drop in barometric pressure and a rise in temperature will cause convexity, where the glass bows out from the middle of the gas filled space.

OPTICAL DISTORTION IN GLASS

Wind load

Heat-treating helps with wind load, but it doesn't help with the center of glass deflection. Whether the glass is annealed, heat-strengthened or fully tempered, the deflection due to uniform wind loading is all the same. Deflection occurs when the glass physically bows into or out of the building because of positive and negative uniform wind loads.

Glazing pressure on the glass

When glass is glazed, excessive pressure on the edge can force the glass to change its shape from flat to concave or convex. This will immediately increase the amount of distortion in the reflected image.

Thickness variance along lite

Being a natural product akin to wood, every sheet of glass is different from any other. Even within a single sheet you can have minute differences in glass thickness and at the borders of these changes we can observe convex or concave conditions on the glass surface that will contribute to the reflected image being distorted.

Air space

An IGUs insulation comes from the characteristic of it being a pressurized air space. As we rise in altitude relative to point of manufacture or add heat the airspace expands stretching the glass and changing the surface shape. The opposite application of less altitude or temperature will compress the airspace. This will happen continuously on the IGU and cause distortion in the reflected image that will change based on the time of day, season, and so on.

Heat treatment

During the process of heat treatment, the glass is heated to a point where it begins to move towards a liquid state. The surface undergoes physical changes which can include bends at the trailing edge of the glass (end kink), small (.008") rises and falls of the surface (roll wave), or even overall bowing of the glass. These shape changes of course contribute to creating convex and concave conditions on the glass surface that will distort reflected images. They are intrinsic to the heat treatment process and cannot be eliminated.

Lamination

When two pieces of glass are adhered together by an interlayer, any distortion between the two is interacting and may increase the cumulative distortion. If the lites are heat treated, not only will the heat-treated distortion be added to each other, but also it is possible for lens effects to be created based on the shape of two opposite surface areas.

OPTICAL DISTORTION IN GLASS

Reflective coatings

When it comes to clear glass there is relatively low reflection and so while distortion has always been there it was not the first thing that a person would notice when looking at the glass. As the industry has looked to low emissivity coatings to increase insulation we have also added to the reflective properties of the glass. This movement to more reflection allows all these distortion variables that once would not be an issue to be much more noticeable.

Multiple lights

When we begin to build IGUs, we add the distortion from each individual glass light together. A triple glaze IGU with heat strengthened Low-E glass that has been laminated and glazed with too much pressure along the unit edges would produce some of the most distorted reflected images. Any time that one begins adding reflective and strengthening attributes together they accept the performance of that material at the cost of increasing the amount of reflected distortion the material will have.

INDUSTRY STANDARDS

As distortion is an inherent characteristic of glass there are currently no industry standards to address how much distortion is too much. Both the standards referenced below concede that reflective distortion is a characteristic of heat treated glass. Until there is a standard, “acceptable” is based upon subjective interpretation.

ASTM C 1048 – 04

7.4.1 “...The original flatness of the glass is slightly modified by the heat treatment, causing reflected images to be distorted....”

7.4.2 “...Fully tempered and heat-strengthened glass that has been made in a horizontal furnace may contain surface distortion (for example, picture framing, heat distortion, or roller wave distortion. Distortion will be detected when viewing images reflected from the glass surface...”

7.4.5 “Regardless of glass flatness, the degree of reflected distortion perceived is largely due to the characteristics or symmetry of the object being reflected. Linear objects (such as building curtain walls and telephone poles) and moving objects (such as cars) may appear distorted. Irregular and free form objects such as trees and clouds will appear to have little perceived distortion.”

OPTICAL DISTORTION IN GLASS

7.4.6 “Specified bow and warp limits may not adequately define or control the distortion that may become apparent after glazing.”

CAN/CGSB-12.1-M90

8.2 “...Tempered glass by the nature of the process, is not as flat as annealed glass particularly along the edges. The deviation from flatness depends on thickness, width, length, and other factors. Usually, greater thicknesses yield flatter products...”

ALL WEATHER WINDOWS GLASS INITIATIVES TO ADDRESS DISTORTION

All Weather Windows has adopted best practices to minimize the reflected distortion, however as distortion is an intrinsic characteristic as explained above, we can only take steps to minimize it, we cannot prevent it. We produce all heat-treated glass for a given project in the same equipment using the same processing parameters.

At the end of our tempering line a zebra board is used as a visual inspection of the distortion in every piece of glass. While zebra boards are not 100% effective in detecting all types or degrees of distortion it does allow a 100% inspection of our glass for sudden or drastic changes in the distortion. Glass found with excessive distortion gets rejected and reprocessed.

We measure and record roller-wave in every shift on the heat treatment line. These recordings are carried out by our trained operators according to our quality inspection process. Data collected is regularly reviewed by our quality team and any glass found to be beyond our control limit is rejected and corrective action is taken to our process.

Since distortion is very subjective, we recommend building sample units to install in job site conditions. This will allow us to evaluate the optical aesthetics of a specific heat-treating process. We also recommend using thicker glass which is less prone to distortion.