VITRUM
INDUSTRIES LTD

Technical Bulletin

V-TB-1-A

"Reflected Image Distortion in Architectural Glass"

Overview

This technical bulletin addresses the phenomenon of distortion in architectural glass.

The Glass Industry continues to raise the level of insulation in windows to meet the customer demand for energy efficiencies through the use of glass coatings that reflect radiant energy back to it's source.

At the same time new safety features in glass have been developed such as lamination and heat treatment to make glass less fragile to the point that it can stop bullets.

In the quest for higher performing construction material both in terms of low emissivity and high strength we have a cost to pay at this time. Distortion in reflected images has been increasingly noticeable by end customers in high performance reflective and heat strengthened glass. Distortion has always been present in glass, however as the Industry continues to push the performance of the material, distortion becomes more pronounced. This is particularly true when we begin combining the different elements of strength and reflection together into complex high performance insulated units.

What is Distortion?

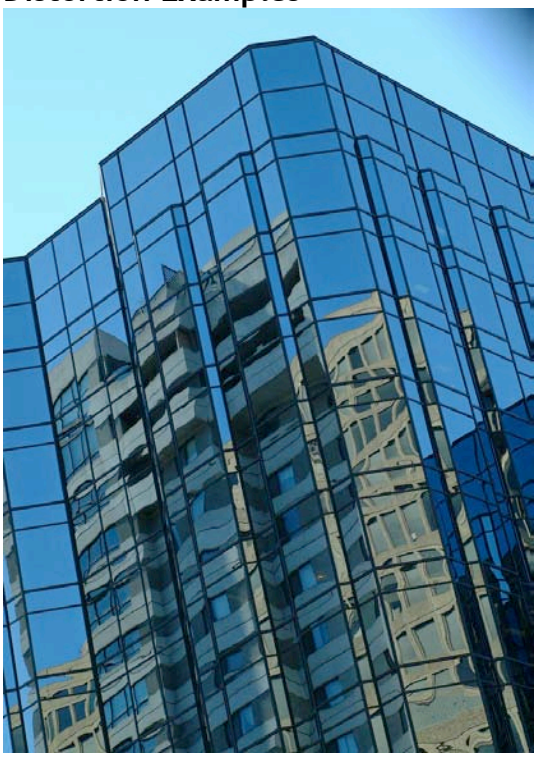
We see reflected images in glass because light rays moving in wave fronts bounce off of the surface and return to the eye. When glass is flat, the reflected image is seen as normal with the light rays reflecting at equal but opposite angles.

When light wave fronts bounce off of curved glass, the angles are no longer equal and this causes the reflected image to be modified.

On a concave surface the reflected image appears to be short and thin while on a convex surface the image appears stretched.

Combing the two effects as seen in heat treated glass with roll wave distortion can create a reflection that can stretch and compress based on the observer's movement in relation to the glass surface.

Distortion Examples



**Note the irregularly shaped flags and trees have less noticeable distortion to their reflective image than the linear lines of the building.*

Contributing factors

Reflected distortion is an inherent characteristic of glass and many variables contribute to the overall distortion of the image.

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 Insulating Glass (IG) unit's 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 IG unit 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 adding to each other, but also it is possible for lens effects to be created based on the shape of two opposite surface areas.

Reflective coatings

"If it is normal how come I have never seen it before?"

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 IG units we are adding the distortion from each individual glass light together.

A triple glaze IG unit 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 are accepting the performance of that material at the cost of increasing also 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 standards concede that reflective distortion is a characteristic of heat-treated glass.

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."

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…"*

What Vitrum does to address Distortion

Vitrum has adopted best practices to minimize the reflected distortion found in our units, however as this is an intrinsic characteristic we can only take steps to minimize it, we cannot prevent it.

Qualitatively at the end of our tempering line a Zebra Board is used as a visual inspection of the distortion in every load 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 and allows for immediate correction.

Quantitatively we use Statistical Process Control Tools to monitor the measured roller wave with a calibrated roll wave distortion gauge. We measure the roll wave every recipe change or every two hours whichever comes first. Any glass found to be beyond our control limit is rejected and corrective action is taken on our process.

The positioning of the roll waves can assist in masking noticeable distortion and so as standard practice Vitrum Industries tempers the glass so that the distortion waves run parallel to glazing base. An observer walking past the building will not see a distortion when tempered this way. It removes the most noticeable and dizzying of distortion opportunities. It should be noted that an observer approaching the building at 90 degrees should be more likely to detect distortion as a trade off in this methodology.

Distortion can truly be in the eye of the beholder and so Vitrum recommends that full sized production run mock ups be created with the customer and viewed at the final installation location so that our customer and their stake holders can confirm that the product make up will deliver aesthetically while providing the performance specifications required.

Want to know more?

For more on distortion the following documents are recommended:

ASTM C 1048 – 04 Standard Specification for Heat-treated Flat Glass-Kind HS, Kind FT Coated and Uncoated Glass

CAN/CGSB-12.1-M90 Tempered or Laminated Safety Glass

GANA Glass Information Bulletin: GANA LD 01-1003 “Design Considerations for Laminated Glazing Applications”

GANA Technical Glossary: Distortion

GANA Specification No. TD 04-03-26 “Standard Test Method for In-Plant Measurement of Roll Wave in Heat-Treated Architectural Glass”

Cardinal Glass Technical Service Bulletin: Bulletin #IG21 – 07/04 “Optical Distortion in Laminated Glass Fabricated with Heat-Strengthened Glass Substrates”

Cardinal Glass Technical Service Bulletin: #IG20 – 07/04 “Distortion in Glass Products”

Pilkington Glass Toughened Safety Glass –Technical Information

“I need security glass” Glass on Web Article,
www.glassonweb.com/articles/article/172/

“The dynamics of ceramic rollers and operating and maintenance practices to produce quality tempered glass” International Glass Review, Issue 2 – 2001

“Old Zebra Boards Give Way to New Roller-Wave Gauges.” Glass Magazine, September 2003