Distortion in Glass Products

Glass distortion can be related to a number of factors and is mostly caused by environmental conditions and glass fabrication processes. Glass distortion is subjective and the degree of perceptive distortion is influenced by the viewing angle, distance away from window, objects being viewed, sky conditions, and glass thickness. Since it is very difficult to assess the degree of distortion or bow in insulating glass products, glass having distortion or bow should not be judged for their worthiness by an aesthetic evaluation alone.

Monolithic Glass Distortion

There are many reasons distortion occurs in monolithic glass products. These reasons may include:

- Glazing pressure around the periphery of the glass
- Windloads which bend and flex the glass
- The heat treatment processes used to fabricate heat-strengthened and tempered glass products for:
  - Resisting high windloads
  - Meeting safety glazing requirements
  - Reducing thermal breakage potential

Insulating Glass Distortion

The causes of distortion are the physical behavior of IG units under weather and installation conditions. While these conditions are simple to understand, they are impossible to control. It is amazing to recognize glass's ability to adjust through glass deflection to these extremely high load forces, and the durability of the edge seal.

An insulating glass unit is a flexible pressure chamber. It contains the pressure of the elevation, barometer, and air temperature that was in the manufacturing plant at the time the unit was sealed. Since these weather conditions change daily - or even hourly - no two units have the identical built-in air pressure.

The unit's edge seal receives the major attention in design because of its ability to produce long-term IG unit field performance. It is recognized that the most positive and attainable action to control high sealant stress is to permit the deflection of the glass lights.

The glass in a sealed insulating glass unit will deflect if the pressure in the unit's air space is different than that of the surrounding environment. The degree of glass deflection depends upon the difference in these two pressures, the size of the IG unit, its glass and air space thicknesses, and its aspect ratio.

The various pressures that cause IG unit distortion are sometimes additive and sometimes counter balancing. For insulating glass, distortion can be caused by:

- Glazing pressure around the periphery of the glass
- Windloads
- The heat treatment process used for fabricating heat-strengthened and tempered glasses
- Changes in ambient temperature
- Changes in elevation from where the insulating glass units were originally fabricated
- Changes in barometric pressure

Terminology

Glazing pressure around the periphery of the glass occurs when monolithic glass or insulating glass is installed in a sash frame or fastened down into an opening. The amount of pressure applied around the edge of the glass may cause the glass to bow or bend.

Windloads will cause the glass to deflect and create optical or viewing distortions as the glass bends.

The heat treatment processes used to fabricate heat-strengthened and tempered glass products require the glass to be heated to approximately 1,200 °F and quickly cooled. This process, although making the glass significantly stronger, produces undulations in the glass called roller wave, bow, and kink (see figure IG18-1).

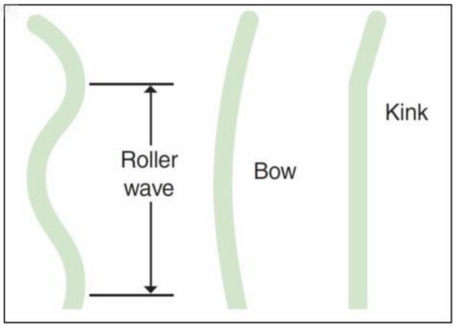


Figure IG18-1

Cardinal measures these attributes at the time of manufacture in order to reduce these effects. This distortion is very subjective and is more apparent when viewed at critical angles from the exterior. Currently there is no field measurement for these types of distortion.

Changes in ambient temperatures will cause the glass to have a positive bow (Figure IG18-2) or negative bow (Figure IG18-3). A positive bow occurs when the airspace temperature of the insulating glass (IG) unit becomes warmer than the IG fabrication temperature. A negative bow occurs when the airspace temperature of the IG unit becomes colder than the fabrication temperature.

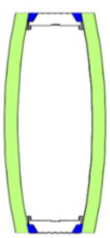


Figure IG18-2:
Positive Glass Bow

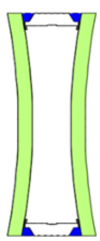


Figure IG18-3:
Negative Glass Bow

Changes in elevation from where the IG unit was originally fabricated will create a positive or negative bow in the glass. If an IG unit is installed at a higher altitude, the glass tends to bow outward (Figure IG18-2) in the shape of a positive curved lens. If the IG unit is installed at a lower altitude, the glass tends to bow inward (Figure IG18-3) like a concave lens. Both negative and positive bows may create an optical distortion in reflection. Installation of a capillary tube may reduce this effect from occurring.

Changes in barometric pressure will also cause the glass to deflect negative or positive. An increase or decrease in barometric pressure, from when the IG unit was originally fabricated, will cause the glass to have a positive bow (Figure IG18-2) or negative bow (Figure IG18-3) respectively.

The degree of glass distortion is influenced by the glass thickness, airspace gap, IG unit size, temperature, barometric pressure, window installation altitude, and IG unit fabrication tolerances.

Example: Let's consider the forces presented by the environmental conditions of elevation changes, temperature changes, and barometric changes. When an IG unit is installed at an elevation above that at which it was made, the lower elevation pressure causes the two glasses to bow outward. As the elevation difference increases, the relatively higher air space pressure becomes more dominant producing greater deflection.

An IG unit made in St. Louis (505' elevation) and glazed in Cincinnati (1,063' elevation) will take a convex shape when experiencing this minus pressure change of 36 PSF (or that produced by a leeward 118 MPH wind). Conversely, an IG unit made in Atlanta and glazed in Philadelphia will have concave bowed glasses due to the drop in elevation of 1,000 feet, or the equivalent of a 168 MPH wind. Seventy percent of our states have elevation differences within a state of over 500 feet. Sixteen states have elevation on differences of over 1,000 feet.

Reflective Image Distortion

When light falls onto a smooth glass surface, some rays are transmitted through, some are reflected back, and some are absorbed. If the incident rays are directly perpendicular to the glass surface, they are reflected straight back as shown in Figure IG18-4.

If the incident rays in figure IG18-4 (2, 3, and 4) fall obliquely upon the glass surface, their reflective rays bounce back at the same angle but to the other side of the normal perpendicular. The angle of incidence (A) always equals the angle of reflectance (A1).

As the transmitted light rays enter the glass, as shown in Figure IG18-5, they are abruptly bent (refracted) at an angle (B) of lesser degree than the incident angle. As the refracted rays reflect from the second glass surface, it is again refracted as it leaves the first glass surface at an angle equal to the original incidence angle.

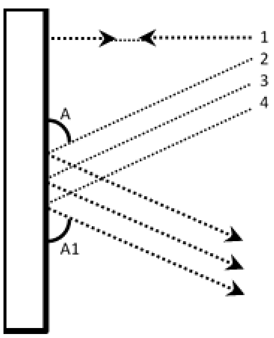
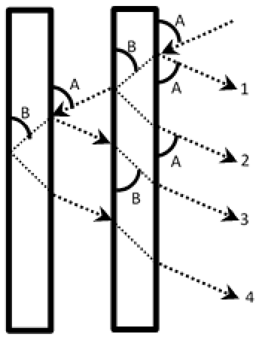


Figure IG18-4



IGFigure 18-5

For each light of glass there are two reflected images: a primary image and a secondary image. With a dual pane insulating glass unit, there are two primary images (surfaces #1 and #3) and two secondary images (surfaces #2 and #4). See Figure IG18-5.

The spacing of these four images from each other will increase and become more noticeable as the incident angle decreases, the glass thickness increases, and the air space increases. (These four images can be seen by holding a lighted match near an IG unit and viewing from an angle.)

When light rays strike a curved glass surface, they reflect in different directions obeying the law of the angle of incidence equals the angle of reflection. All objects being reflected from curved glass surfaces are distorted from their actual form. If the glass curvature is concave, the reflected light rays are projected inward toward a central point causing the reflective image to appear to be short and thin (see Figure IG18-6 A).

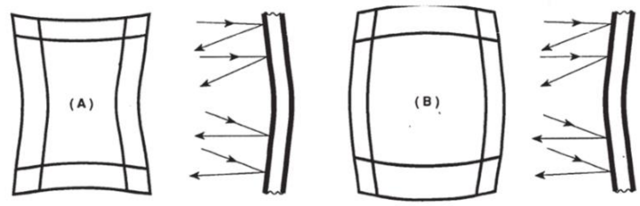


Figure IG18-6

If the glass curvature is convex, the reflected rays are projected outward causing the reflective image to be stretched out in both directions (Figure IG18-6 B). In insulating glass units experiencing load changes due to elevation, air temperature or barometer, both glass lights will be in reversed curvature, altering significantly the shape of the object being reflected.

Light, in its transmission, refraction, and reflection behaviors, is rather easy to understand when the glass is flat. The reflective images seen are multiples but exactly like the object reflected. However, when we deal with sealed insulating glass units, 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 IG units.

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