

## Distortion in Heat Treated Laminated Glass

Laminated glass often incorporates multiple plies of heat-treated glass in order to achieve high level of resistance to thermally and mechanically applied loads. This type of laminated glass is typically used in applications requiring safety glazing, security glazing, burglary resistance, sound control, ultraviolet-filtering and hurricane resistant glazing products. While this glass provides excellent safety and security during storms and accidental contact, it can also be aesthetically displeasing.

When viewing images through or in reflection from laminated glass, the images may appear distorted. This distortion could arise from internal variations in the interlayer thickness, heat-treatment of the glass, differences in glass types used in the laminated construction, and the manner in which the piece is glazed. Some distortion, as noted in the following paragraphs, is inherent in the glass fabrication process and is not a cause for rejection.

### Heat Treatment:

- In an effort to increase the resistance to thermally and mechanically applied loads, multiple plies of heat-treated glass are often used in laminated glass.
- Precision Glass Industries produces heat strengthened and fully tempered glass by heating annealed glass in a horizontal tempering furnace to a temperature at which the glass becomes slightly plastic. Immediately after heating, the glass surfaces are rapidly cooled by quenching with air. The original flatness of the glass is slightly modified by the process creating some level of surface distortion (picture framing, heat distortion, or roller wave distortion).
- When combining multiple layers of heat-treated glass, in the case of laminated glass, the inherent distortion characteristics of each lite of heat-treated glass can become accentuated.

### Different Glass Types/Lens Effect:

- Different tints of glass absorb or reflect heat differently and therefore must run on different heating cycles in the tempering oven (the same is true for coated or reflective glass types). A different cycle results in a slightly different distortion profile.
- Using two different heat-treated substrates when laminating typically results in a greater degree of visible distortion due to the lens effect of having the glass surfaces out of phase or non-parallel when bonded together in the laminated glass makeup. The lens effect can result in a magnification of objects when they are viewed through the glass in transmission as well as when viewing reflected images. This effect is especially pronounced at the perimeter edges of the glass.

### Installation, Background and Viewing Angle:

- The visibility of transmitted distortion is greatly affected by surrounding conditions, glazing orientation and viewing angles. If the transmitted image is a uniform blue sky, the transmitted distortion that appears in the laminated product appears without distortion. If the same piece of tempered laminated glass is transmitting multiple grid lines (i.e., trees), the transmitted image appears distorted.
- In many applications, edge kink distortion is not visible because the edges are captured. However, when installed in a butt-glazed manner, without any sort of framing system hiding the vertical edges of the glass, it is possible to view an object or objects through the glass at the vertical joining edges of two panels simultaneously. The added visibility of the edge kink combined with the lens effect from the different glass types may accentuate the appearance of distortion and because objects viewed in transmission or reflectance to appear disconnected.
- It should be noted as well that distortion of images, whether viewed in transmission or reflectance may be accentuated when viewed at angles other than normal (90degrees) to the surface, often the more acute or obtuse the angle, the greater the distortion.

When inspecting tempered laminated glass, the following ASTM standards are the applicable industry guidelines:

ASTM C-1172 Standard Specification for Laminated Architectural Flat Glass

ASTM C-1048- Standard Specification for Heat Strengthened

### Fully Tempered

All visual inspections should be made with the naked eye viewing samples in the vertical position at a distance of 10ft (3.0 m) and a viewing angle of 90° to the specimen using daylight (without direct sunlight) or other uniform diffused background lighting simulates daylight (minimum 1700 lux measured at the surface of the glass facing the light source).