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TECHNICAL DOCUMENT (FGTD-17.3)

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ANISOTROPY (IRIDESCENCE) IN HEAT-TREATED GLASS

17.3.1 OVERVIEW

Heat-treated glass (heat-strengthened or tempered) can have an optical phenomenon that is called strain pattern or quench pattern. This phenomenon can appear as faint spots, blotches, or lines. This is the result of the air quenching (cooling) of the glass when it is heat-treated and is termed as anisotropy or iridescence.

17.3.2 THE HEAT-TREATMENT PROCESS

In order to provide the required resistance to thermal and mechanical stresses, and to achieve specific break patterns for safety glazing applications, annealed float glass is strengthened through a thermal process known as heat-treating. Heat-treating includes both heat-strengthened and fully tempered glass. The most commonly used process for heat-treating architectural products requires glass to be cut to the desired size and shape, edges prepared to the specified condition, surfaces and edges to be thoroughly washed and for the lite of glass to be transported through an oven and uniformly heated to near its softening point of approximately 621 °C. Upon exiting the oven, the glass is rapidly cooled (quenched) by blowing air uniformly onto all surfaces simultaneously. The quenching/cooling process places the surfaces of the glass in a state of high compression and the central core in compensating tension.

The high velocity air of the quench process is applied through air nozzles or slots. Glass surfaces directly opposite the nozzles or slots achieve a slightly higher level of surface compression than adjacent areas. This creates a very slight change in density causing the glass to become optically anisotropic. Optically anisotropic means that the appearance of light passing through the glass differs as your eye moves across the glass. When polarized light from the sun passes through the heat-treated glass it experiences a phase shift. The areas of lower density (directly under the quench nozzles) have a different phase shift than the areas with higher density (away from the quench nozzles). These slight differences in density result in light and dark areas observed in the glass.

17.3.3 PATTERN VISIBILITY

While not normally visible, a pattern of perceived faint light and/or dark spots or lines in heat-treated glass may become apparent under certain light and viewing conditions. The “quench pattern” is most apparent under polarized light with a visible horizon and viewed at an oblique viewing angle to the glass surface. The visibility of the pattern decreases as the viewing angle to the surface of the glass

increases. When viewing from the interior of the building, the quench pattern may be visible from a 10° viewing angle and not apparent at a 90° viewing angle from the surface of the glass. When viewing the glass in reflectance from the exterior of the building, the quench patter n may be visible when looking at the glass surface at a 30-60° angle. Visibility of the quench pattern may be accentuated with thicker glass, tinted glass substrates, coated glass and multiple lites of heat-treated glass in laminated or insulating glass products.

As frequently seen in back and side lites of automobiles, the quench pattern in the fully tempered glass can become more visible when wearing polarized sunglasses. Polarizing filters or lens for cameras will create the same phenomena and may cause the pattern to become more visible.

17.3.4 ANISOTROPY EXPLAINED IN GLASS STANDARDS AND MANUALS

The heat treatment process results in a higher surface compression directly opposite the air quench, air nozzles or slots. The higher compression areas are denser and can exhibit a darker appearance under some viewing conditions. The American Society for Testing and Materials (ASTM) has a standard on heat-treated glass products. This standard is C1048-04 Heat Treated Flat Glass – Kind HS, Kind FT Coated and Uncoated Glass. In this standard, strain pattern is recognized and identified as follows:
7.5 Strain Pattern – "In heat strengthened and fully tempered glass, a strain pattern, which is not normally visible, may become visible under certain lighting conditions. It is a characteristic of these kinds of glass and should not be mistaken as discolouration or non-uniform tint or colour."

In addition, the Glass Tempering Division of the Glass Association of North America (GANA) defines Strain Pattern as follows:
"The tempering process places glass under very high compression on the surface and high tension in the core of the glass. This results in a specific geometric optical pattern in the glass which is not normally visible, but which may become apparent under certain conditions of illuminations, especially when light is polarized, such as a skylight or other forms of reflected light. The colors of the strain pattern are sometimes referred to as iridescent, or the general condition as iridescence. The pattern that is seen under certain lighting conditions may vary from manufacturer, depending on the design of the cooling apparatus. Strain pattern is characteristic of all fully tempered glass."

The intensity of the quench or strain pattern is influenced by the viewing angle, lighting conditions and by the perceptiveness of the viewer. It is nearly impossible to eliminate the strain pattern or quench pattern in heat treated glass products.

The strain or quench pattern may be accentuated if two lites of heat-treated glass are used in an insulated glass unit. These strain patterns or quench patterns should not be viewed as a defect in the glass as they cannot be eliminated in the heat treatment process. The spots are not an indication of absolute tempering level; they simply show areas of relatively more, or less, tempering stress. Given the nature of the quenching process it is physically impossible to quench a plate with absolute uniformity. The degree of tempering and the uniformity of tempering throughout the plate can be tested by other methods such as surface stress instruments or by examining the break pattern after fracture.

GANA has also published the following in the Glass Information Bulletin GANA TD-05-0108 on Quench Patterns in Heat Treated Architectural Glass:
Glass used in architecture today commonly includes clear and tinted glass substrates, low-emissivity and solar-control coatings, decorative ceramic-frit patterns and safety glazing considerations that require glass to be heat-treated. Heat-strengthened and fully tempered glass is designed to meet increased thermal and mechanical stresses, or other specified physical criteria. As a result of the heat-treating fabrication process, quench patterns/marks or what is often referred to as a "strain pattern," may become visible in heat-strengthened and fully tempered glass under certain natural or polarized lighting conditions.

The intensity of the strain pattern may vary from lite to lite, and/or within a given lite. The presence of a strain pattern or the perceivable differences in the strain pattern is not a glass defect or blemish and is not cause for rejection. In addition, the presence of a strain pattern does not alter the structural integrity or safety of the glass lite.

17.3.5 GLASS INSPECTION

Construction sites may yield viewing angles and conditions that cause the quench pattern to become visible. However, upon completion of construction, the presence of interior walls, finishes, furniture and plants frequently results in the strain pattern being less visible or not visible at all.

The stresses introduced in the heat-treating of glass are an inherent part of the fabrication process, and while they may be affected or altered depending on the heating process, controls and/or quench design, they cannot be eliminated. Design professionals should be aware that quench patterns are not a defect in heat-treated glass and, therefore, are not a basis for product rejection.

17.3.6 EXAMPLES OF ANISOTROPY