NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB18-08 (2023)**

Methods of Measuring Optical Distortion in Heat-Treated Flat Architectural Glass

Introduction

As a result of heat-treating glass, optical distortions may occur from out-of-plane deformations of the glass surface. While ASTM C1048 *Standard Specification for Heat-Strengthened and Fully Tempered Glass* specifies values for overall bow and localized bow, currently, there are no industry-wide standards that specify acceptable values for optical distortion. However, there are existing methods/instruments to measure optical distortions. The methods/instruments referenced in this document are designed and intended for in-plant use only. These methods for measuring distortion cannot be applied in the field on vertical glazing and cannot be used on insulating glass units.

Definitions

Optical Distortion – Alteration of viewed images in transmission or reflection (see Figure 1) caused by variations in glass flatness or inhomogeneous portions within the glass. Types of optical distortion include:

> *Roll Wave* – A repetitive wave-like departure from flatness in glass that results from heat treating glass in a horizontal roller hearth furnace (see Figure 2). Roll wave excludes edge effects such as edge kink and distortion influenced by assembly or installation.
>
> *Edge kink*, *edge lift* - An abrupt deviation from a flat plane or normal bow contour, most commonly found near an edge of the piece of heat-treated glass. A kink or lift is localized compared with contours of bow or warp.
>
> *Hammer* or *pocket distortion* - Craters in the glass surface and related distortion resulting from uneven heat conduction from the ceramic rollers in the furnace.
>
> *MilliDiopter (mD)* - The *diopter* (D or dpt) is the unit of measurement for distortion (lens power) in a curved surface equal to the reciprocal of the focal length (1/f) (see Figure 3). A *milliDiopter (mD)* equals 1/1000 of a diopter and is the accepted unit for quantifying the magnitude of roll-wave distortion in flat glass.

Figure 1: Example of optical distortion viewed in reflection from a glass surface

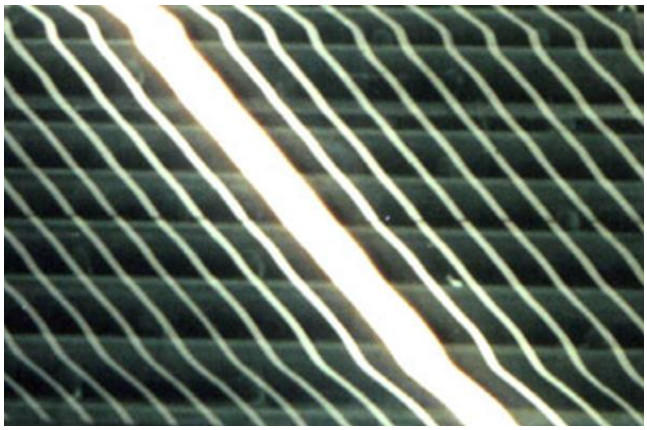

Figure 2: Roll wave in glass viewed in reflection

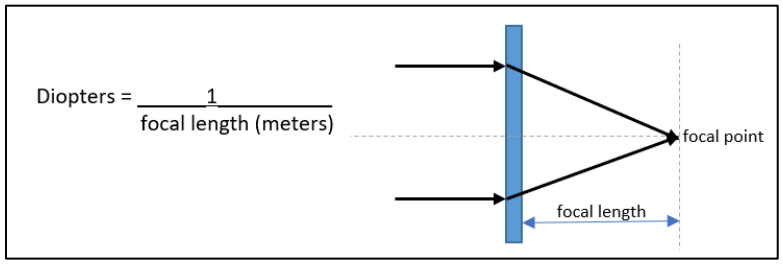

Figure 3: The reciprocal of the focal length is the diopter

Methods to Evaluate Distortions

Surface Contact Gauges

Surface contact gauges (e.g., "Flat-Bottom Gauge", "Three-Point Contact Gauge" or similar devices- see Figure 4) are used for measuring roll wave in accordance with ASTM C1651 *Standard Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Glass*.

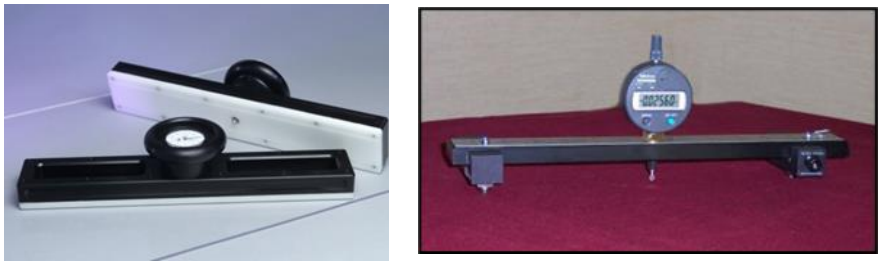

Figure 4: Surface contact gauges: flat-bottom (left) and three-point contact gauge (right)

These devices are generally used off-line and are moved across the glass surface (making contact) perpendicular to the rollers in the furnace (parallel to the direction of travel). The devices will measure out-of-plane deformation of the glass surface, i.e., roll wave peak-to-valley depth. Using the formula stated in ASTM C1651, this measurement, in inches or millimeters, can then be converted to optical power and expressed in millidiopters (mdpt).

Digital Photography Methods

Digital imaging methods are used to measure optical distortion. One digital imaging method is described in ASTM C1652/C1652M *Standard Test Method for Measuring Optical Distortion in Flat Glass Products Using Digital Photography of Grids*.

Figure 5: Example of online digital imaging method to measure optical distortion, the LiteSentry Osprey system. Photo courtesy of LiteSentry-SoftSolution.

Depending on their design, these devices can be used on-line or off-line (see Figure 5). They are non-contact and measure the entire surface of the glass. Using digital cameras, lighting systems and fixed reflected images, these systems can have a measurement resolution of 5 mdpt. Computer software analyzes the digitized images and displays a surface distortion waviness (roll wave, edge kink, edge lift, hammer or pocket distortion, and any other type of optical distortion) or quantifies the lens power or optical distortion (mdpt) for approximately each square inch (645.16 mm^2) of the entire glass surface.

Information from these systems may be presented in many ways, including maximum distortion (in roll wave peak-to- valley depth and mdpt), and positive and negative lens power. Image analysis software can also project a 3D visualization of optical topography.

References

- ASTM C14.11 Subcommittee is part of ASTM C14 Committee on Glass and Glass Products available at www.astm.org
- ASTM C1048 *Standard Specification for Heat-Strengthened and Fully Tempered Glass*
- ASTM C1651 *Standard Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Glass*
- ASTM C1652 / C1652M *Standard Test Method for Measuring Optical Distortion in Flat Glass Products Using Digital Photography of Grids*

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