GLASSWERKS – TECHNICAL BULLETIN

ARCHITECTURAL GLASS DISTORTION – QUALITY STANDARDS

TECHNICAL DOCUMENT: GW-TB-002

PURPOSE AND SCOPE

This bulletin provides an overview of optical distortion as it relates to architectural glass, including annealed, heat-treated (heat-strengthened and fully tempered), laminated, coated, and insulated glass units (IGUs). The intent is to set clear expectations for stakeholders, outline contributing factors, and reference industry-accepted principles from leading technical bodies such as ASTM and the Fenestration & Glazing Industry Alliance (formerly GANA).

Optical distortion is **inherent to the manufacture and processing of flat glass**. It cannot be eliminated but can be managed through proper design considerations, fabrication controls, and realistic expectations.

UNDERSTANDING DISTORTION

Reflected images appear in glass because wavefronts of light strike the surface and return to the observer at equal and opposite angles. When the glass surface is flat, reflections appear undistorted.

When the surface deviates from flatness—whether concave, convex, wavy, or thermally altered—the angles between the incident and reflected light change. This produces a visual effect commonly perceived as bending, stretching, compressing, or shimmering of the reflected scene.

- Concave areas compress reflected images.
- Convex areas stretch reflected images.
- Mixed surface conditions, such as those caused by roller wave or localized bow, create reflections that vary as the observer moves.

This phenomenon is **normal** and is influenced by the manufacturing, processing, installation, and environmental conditions of the glass.

INDUSTRY CONTEXT

Modern architectural glazing demands:

- High-performance coatings for improved thermal insulation
- Increased glass strength through heat treatment
- Enhanced safety and security (lamination, multi ply constructions)

These advancements inherently increase the visibility of distortion. As reflectivity increases—particularly with low E and solar-control coatings—surface irregularities that were once subtle become more noticeable.

Distortion is not a defect, but an *expected characteristic* of high-performance heat-treated and reflective glazing systems.

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CONTRIBUTING FACTORS

- **Glazing Pressure**
  Excessive point or edge loading during installation can mechanically alter the glass surface, inducing concave or convex curvature. This intensifies reflected distortion and falls outside fabrication responsibility.

- **Natural Thickness Variation**
  Float glass has minor but inherent thickness variations. Where thickness transitions occur, localized surface curvature can develop. These areas may appear as subtle dips, rises, or waves and may influence the pattern of reflected images.

IGU AIRSPACE PRESSURE

Insulating glass units respond to differential pressure caused by:

- Temperature changes
- Altitude differentials between manufacturing and installation
- Daily environmental cycling

As the sealed airspace expands or contracts, the glass lights flex slightly, creating seasonal or diurnal distortion patterns.

HEAT TREATMENT EFFECTS

Heat-strengthened and fully tempered glass undergo controlled heating and rapid cooling. During this process, the glass reaches a semi-viscous state and may experience:

- Roller wave
- Edge kink
- Overall bow or warpage
- Localized surface undulation

These characteristics are intrinsic and unavoidable, though they can be minimized through proper furnace calibration. GANA notes that heat-treated glass may display visible roller wave and surface distortion when viewed in reflection, particularly against linear backgrounds.

LAMINATION EFFECTS

When two or more plies are laminated:

- Distortion from each lite can combine
- Heat-treated plies may amplify each other's roller wave

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- Opposing surface geometries can create lensing effects

Complex multi ply constructions (e.g., security glazing) will exhibit more pronounced optical distortion.

REFLECTIVE AND LOW-E COATINGS

Reflective coatings make surface irregularities more noticeable, especially when the reflected scene includes horizontal or vertical lines (buildings, poles, muntins). Irregular objects such as trees show substantially less perceived distortion.

MULTIPLE LITES IN AN IGU

Each lite contributes its own optical profile. When combining:

- Coated surfaces
- Heat-treated lites
- Laminated plies
- Triple glazed constructions - the cumulative effect can significantly increase overall distortion.

INDUSTRY STANDARDS AND REFERENCES

There is no industry standard defining acceptable levels of reflected distortion, and no specification guarantees a distortion-free surface.

- **Per ASTM C1048**
  - Heat treatment "modifies the original flatness" and "causes reflected images to be distorted."
  - Distortion in reflected images varies by object type; linear features are most affected.
  - Warp/bow tolerances do not predict perceived distortion in installed conditions.

- **Per CGSB 12.1**
  - Tempered glass will not be as flat as annealed glass, particularly near edges.
  - Distortion increases as glass dimensions increase.

- **The Fenestration & Glazing Industry Alliance (formerly GANA) further emphasizes:**
  - Roller wave and heat treatment distortion are inherent characteristics.
  - Environmental and installation conditions contribute significantly to reflected distortion.
  - Distortion should be assessed at typical viewing distances and angles, not by close inspection.

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FABRICATION PRACTICES TO MINIMIZE DISTORTION

While distortion cannot be eliminated, responsible fabrication includes:

- **Visual Inspection**
  Using zebra boards or equivalent optical tools to evaluate roller wave patterns for consistency and to identify sudden changes in process performance.

- **Statistical Process Control**
  Routine measurement of roller wave height and process parameters using calibrated gauges, recorded at defined intervals.

- **Optimizing Roller Wave Orientation**
  Tempering glass so that roller wave runs parallel to the glazing sill reduces the most disruptive distortion patterns for typical walk by viewing. Changes in appearance at 90˚ viewing angles should be expected.

- **Customer Mock-Ups**
  Full-size mock-ups are strongly recommended. Evaluation should occur:
  - At the installation site
  - Under representative lighting conditions
  - At normal viewing distances
  - Mock-ups help confirm that aesthetic expectations align with the realities of high-performance glazing.

LEGAL DISCLAIMER – ASTM-STYLE LANGUAGE

Optical distortion—including but not limited to roller wave, bow, warp, localized lensing, and reflective image variation—is an inherent characteristic of heat-treated, laminated, coated, and insulated architectural glass. These characteristics are not defects and shall not constitute grounds for product rejection.

The manufacturer warrants only that glass products conform to the dimensional and processing tolerances specified in applicable ASTM and FGIA standards. No warranty, express or implied, is made regarding the absence of distortion or the suitability of any product for applications requiring a distortion free appearance.

Performance may vary due to building design, framing systems, installation methods, environmental conditions, and other factors outside the manufacturer's control.

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RECOMMENDED REFERENCE DOCUMENTS

- **ASTM C1048** – Standard Specification for Heat-Treated Flat Glass
- **ASTM C1036** – Standard Specification for Flat Glass
- **FGIA/GANA publications**:
  - Heat-Treated Glass Surfaces & Distortion
  - Roll Wave Measurement Standards
  - Laminated Glazing Design Considerations
- **CGSB 12.1** – Tempered or Laminated Safety Glass Standard
- Relevant Technical Service Bulletins from Industry Manufacturers