Oldcastle BuildingEnvelope®

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Oldcastle BuildingEnvelope®

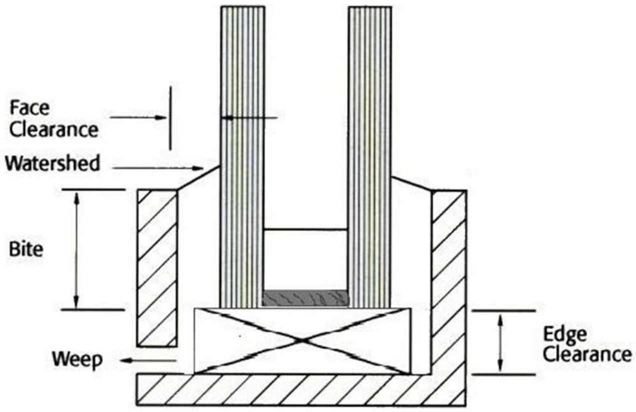
GLAZING INSTRUCTIONS

CAUTIONS

1. Failure of any Oldcastle BuildingEnvelope® product due to incompatibility with any other product not supplied by Oldcastle BuildingEnvelope® (including, but not limited to, blocks, gaskets, glazing sealants, spacers, tapes, plasticizing oils and solvents) voids all warranties and exonerates Oldcastle BuildingEnvelope® from any liabilities.
2. Setting blocks and anti-walk blocks must be silicone for IGUs used in 4-sided SSG, sloped glazing, and with IGUs that have gray silicone secondary sealant. Silicone or silicone compatible EPDM setting blocks and anti-walk blocks can be used in conventional 4-sided captured glazing and vertical 2-sided SSG.
3. Do NOT use razor blades or broadknife blades of any kind to clean glass. Oldcastle BuildingEnvelope® is not responsible for scratches and/or damage caused by window cleaners or other construction tradesmen.
   Follow NGA *Proper Procedures for Cleaning Architectural Glass Products,* available at http://www.glasswebsite.com/techcenter/default.asp.
4. Use of all abrasives, chemicals, or other surface treatments should be spot tested and evaluated under actual use conditions and under various lighting extremes before proceeding with use.

The following Glazing Instructions are intended to assist the design professional and installer. Additional glazing recommendations and guidelines provided by NGA/GANA and FGIA (AAMA/IGMA) must also be followed. If there is any variation in glazing recommendations, the more stringent guideline will apply.

1. **Glass Handling & Protection -** Care must be exercised in the handling and the glazing of glass to prevent edge damage. The glass must not contact the framing members, or other metal components such as screws, during glazing. Glass must be protected from weld splatter, blasting and other impact damage. Alkali or fluorinated materials released from concrete or masonry during rainstorms can stain or etch glass. Weathering steel releases oxides while aging which can result in stained glass if proper periodic cleaning is not done. Solutions used to restore or neutralize masonry surfaces can attack glass and first surface pyrolytic reflective coatings.
2. **Glass Storage -** Glass should be kept on a lean of 5-7° from vertical using broad, sturdy uprights. Never store glass in sunlight without using an opaque cover to protect it. Glass should be stored in a dry, clean and cool location where the temperature is above the dew point. Circulation of dry, cool air is required especially after periods of high humidity and cyclic temperatures. If glass must be stored outdoors, use tarps or plastic coverings to protect it from getting wet, and vent periodically to prevent moisture accumulation. Repeated wetting and drying of glass surfaces can result in staining or etching of the glass.
3. **Glazing Frames -** Frames must be square, in plane, free of any internal obstructions and structurally adequate.
   a. Squareness: 1/8" maximum diagonal difference
      i. Bow: 1/16" maximum per any 4' length
      ii. Plumbness: 1/16" per 6' length
      iii. Corner Joint Offset: must not exceed 1/32" of adjoining members
   b. Design Load Deflection: Unless applicable codes or the design professional establish a more stringent requirement, deflection of framing members supporting glass shall not exceed the length of the unsupported span divided by 175 (L/175).
   c. Dead Load Deflection: Horizontal Framing Member deflection should not reduce glass bite by more than 25% of design dimension, nor reduce edge clearance of glazing below to less than that required to prevent glass to metal contact. Refer to the chart on the following page for recommended clearance and bite values.
   d. Dead Load Twisting: Twisting of the horizontals due to the weight of glass should not exceed 1°, measured between ends and center of each span.
   e. Edge and Face Clearance, and Bite**:** The glazing system must have adequate edge and face clearance to 'cushion' the glass, thermally isolate the glass from framing members, and prevent glass-to-metal contact. An adequate bite is required to provide proper seal; however, excessive bite could increase thermal stresses. Refer to the chart on the following page for recommended clearance and bite values, and exceptions.
4. **Glazing System Water Management –** The edges of insulating, laminated, and spandrel glass should not be exposed to water or other liquids or vapors for extended periods of time, which may result in seal failure, delamination, or coating deterioration and void the warranty. OBE requires either a positive weather seal, or an adequate weep system to prevent such exposure. Setting blocks must not hinder the flow of liquid from the glazing channel.
5. **Glass Installation**
   a. Setting Blocks – All lites of glass should be set on 2 identical setting blocks with a Shore A durometer hardness of 80 to 90. The preferred location is at 1/4 points of the sill. In some cases, it may be necessary to move the blocks equally closer to the corner of the unit but not closer than 1/8 points or 6" from the edge, whichever is greater. The setting blocks should be sized to provide 0.1" of length per square foot of glass but not less than 4" long. Setting blocks should be wider than the IGU thickness in a conventional framing system. In an SSG application, the setting block must support a minimum of half of the outer lite thickness. Setting blocks should not block the weep holes or prevent water from exiting the frame quickly. The thickness of the setting block should provide the recommended nominal bite and minimum edge clearance for the glass. When a lock strip gasket glazing system is used, each setting block should be sized to provide 0.4" of length per square foot of glass area, but not less than 6" long. The lock strip gasket manufacturer should recommend the height of the blocks.
   b. Edge Blocks, or anti-walk Blocks – All dry-glazed lites of glass should have at least one edge block per jamb that has a Shore A durometer hardness between 50 to 70. Blocks should be a minimum of 4" long, placed in the vertical channel and sized to allow a nominal 1/8" clearance between the edge of the glass and block.
6. **Dry-Glazing Methods**
   a. Pressure-Plate Gaskets: These gaskets must apply pressure onto the glass uniformly between 1/8" to 9/16" from the unit edge. The sealing pressure should be in the range of 4 to 10 pounds per linear inch, which should be achieved by tightening the pressure plate fasteners with torque-controlled wrenches. The fasteners should be tightened at quarter points of sill, then quarter points of head, then quarter points of jambs, and then the remaining bolts. Excessive torque on the pressure plate fasteners may contribute to glass breakage, or cause squeeze out of the PIB into the vision area.
   b. Wedge Gasket Glazing: Wedge gaskets must be properly sized and installed so that the gasket is crowded, not stretched. Refer to the system manufacturer's instructions for proper sizing and installation procedure.
   c. Structural Gasket Glazing (Lock Strip Glazing): This system must have a continuous wet sealant applied as a cap bead to the exterior glazing leg.
7. **Structural Glazing Methods**
   a. IG Unit Sightline: For all structurally glazed IG units, the customer must verify that the IG unit is ordered with an IG unit sightline that provides the necessary secondary silicone contact width to resist the lateral loads, while not exceeding a silicone design stress of 20 psi.
   b. Structural Silicone Glazing: It is critical that the structural silicone supplier review the details and project conditions to approve the application, and provide recommendations regarding, but not limited to, application, environmental restrictions, product selection, surface preparation, material selection and structural sealant contact width. It is the customer's responsibility to confirm that the recommendations are followed.
   c. Structural Glazing Tape: The structural glazing tape supplier must review the shop drawings and project conditions to approve the use of their tape in the application. The customer must take extreme care to verify all the written procedures are followed. Do not apply more force to the IG unit edge than what is prescribed in the written instructions while adhering the glass to the framing. OBE will not be responsible for damage to the glass or the IG sealant resulting from excessive pressure to the IG unit edge during installation.
8. **Capillary Tubes -** IGUs that experience an elevation difference of 2,500 feet or more in transportation or installation location from the IGU manufacturing elevation may require capillary tubes. Capillary tubes may not be used with IGUs containing a gas filled air space. It is the customer's responsibility to determine when capillary tubes are required and verify that the IGUs are ordered accordingly. These tubes will be installed on the IGU vertical edge and must be cut, sealed, and then pointed downwards after the IGUs have stabilized for 72 hours (or until flat) at final destination. Oldcastle BuildingEnvelope® Closing Procedure for Capillary Tubes is available on request from any Oldcastle BuildingEnvelope® plant. Failure to follow the Oldcastle BuildingEnvelope® closing procedure will void the IGU warranty.



(1) Specialty glazing system designs such as ones with glazing tape or sealant back-bedding may be designed for reduced face clearance. Deviations from typical clearances should be fully considered within the context of the design and expected performance of the glazing system. Consult glass manufacturer, fabricator, glazing material manufacturer, and/or design professional for relevant performance properties
(2) Annealed glass
(3) Fully tempered and heat-strengthened glass

TYPICAL FACE & EDGE CLEARANCE & BITE

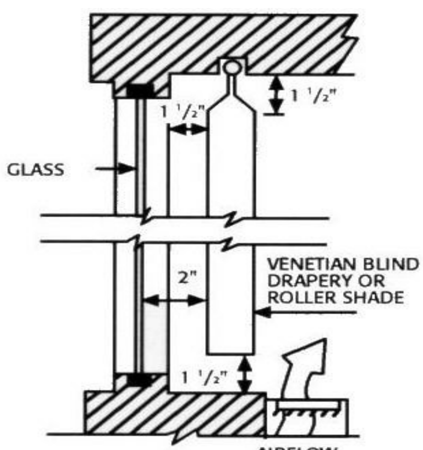
GLASS TYPE	GLASS THICKNESS		MINIMUM FACE CLEARANCE (1)	MINIMUM EDGE CLEARANCE	MINIMUM BITE
	inches	mm	inches	inches	inches
Single Glazing	3/32	2.5	1/16	1/8	1/4
	1/8 (2)	3	1/8	1/8	1/4
	1/8 (3)	3	1/8	1/4	3/8
	5/32	4	1/8	3/16	5/16
	3/16 (2)	5	1/8	3/16	5/16
	3/16 (3)	5	1/8	1/4	3/8
	1/4	6	1/8	1/4	3/8
	3/8	10	3/16	5/16	7/16
	1/2	12	1/4	3/8	7/16
	5/8	16	1/4	3/8	1/2
	3/4	19	1/4	1/2	5/8
	1	25	1/4	1/2	3/4
Spandrel	1/4	6	3/16	1/4	1/2
Insulating Glass	1/2	12	1/8	1/8	1/2
	5/8	16	1/8	1/8	1/2
	3/4	19	3/16	1/4	1/2
	1	25	3/16	1/4	1/2
	1-1/8	28	3/16	1/4	1/2

Thermal Stress

Thermal Stress is created when one area of a glass pane gets hotter than the adjacent area, causing the hotter area to expand at a greater rate. If the stress is too high, then the glass will crack. The amount of thermal stress is dependent on the glass type, size, thickness, shape, and how it is isolated from the framing system. Other factors include building orientation, interior shading devices, exterior shading patterns, heating register location, etc. Heat-strengthening or tempering the glass increases the strength and decreases the chance for thermal stress breakage. The following conditions must be considered when evaluating the effects of thermal stress. When the risk of thermal stress breakage is a concern, heat-treated glass should be used. Oldcastle BuildingEnvelope® Technical Services will offer suggestions on the need to heat-treat glass when requested.

1. **Interior Heat Traps** — These situations occur when there is inadequate air circulation to properly remove heat from the inside surface of the glass. Spandrel areas are a good example of a heat trap since the spandrel cavity does not allow adequate circulation of air. Spandrel glass should always utilize heat-treated glass to minimize thermal stress breakage. Insulation should be held away from the face of the spandrel glass 2 inches but should never be placed closer than 1 inch, and the insulation shall be secured in a manner that will prevent the insulation from sagging onto the glass surface.

In vision areas, air movement over the room side of the glass must not be restricted. Suspended soffits, structural pockets, walls and other building elements placed directly in front of the glass surface must be far enough from the glass surface to allow natural convection, or the glass should be heat-strengthened or tempered.



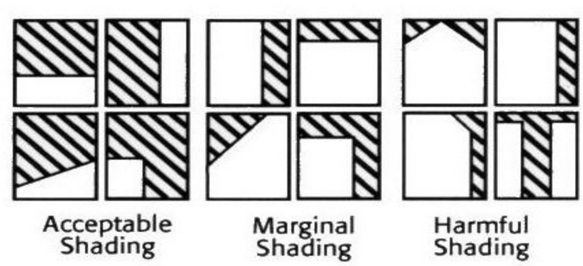
MINIMUM CLEARANCE

2. **Interior Shading** — Draperies, venetian blinds or other interior shading devices must be hung with space to permit natural air movement over the room side of the glass. The following criteria must be met to avoid formation of a heat trap:
A. Minimum 1-1/2" clearance required at the top and bottom, or one side and bottom, between the shading device and the surrounding construction.
B. Minimum 2" clearance between glass and shading device.
C. Heating/cooling outlets must be to the room side of the shading device with airflow directed away from the glass.
D. Use mechanical stops to prevent complete closure of blinds to 60% of closed position.
Heat-strengthening or tempering of the glass may be necessary to offset the effects of a lack of adequate ventilation.

3. **Heating Register Location and Orientation** — In any building, the registers need to be carefully placed in order to ensure that warm air is not being directed at the glass, which can cause isolated areas of the glass to heat up and lead to thermal stress

4. **Exterior Shading** — Shadows cast by overhangs, light shelves, sunshades, surrounding structures, trees and shrubbery can create shading patterns on the glass, creating thermal stress. Maximum stress occurs when 25% or less area of a lite is shaded and the shade includes more than 25% of the perimeter. Generally, horizontal, vertical, and diagonal shading patterns are not as critical as shading that combines several patterns. Double diagonal shading is generally the most critical pattern. See the sketches of typical shading patterns that are labeled "Acceptable", "Marginal", and "Harmful".

EXTERIOR SHADING PATTERNS



Oldcastle BuildingEnvelope®

September 14, 2022

Reference: Typical Glass & Glazing Specification Exceptions and Comments

This document is intended to address typical Glass and Glazing specification exceptions. Any questions regarding specification requirements that are not addressed by this document should be directed to your OBE sales representative.

General Project Requirements

Building Codes: It is the customer's responsibility to order the appropriate glazing material for the application based on the requirements of the applicable building codes.

Specification Requirements: It is the customer's responsibility to order the appropriate glazing material for the application based on the requirements of the project specifications.

LEED / Sustainable Design: Request for LEED submittals should be sent to the OBE glass fabricating plant.

Wind load Analysis: Upon request, OBE will provide a wind load analysis using the computer program Window Glass Design by Standards Design Group based on ASTM E1300. This analysis is not performed by an engineer and should not be considered delegated design.

Glazing Detail Review: Upon request, OBE reviews shop drawings to verify general compliance to the GANA Glazing Manual and attached OBE Glazing Instructions, and NOT to certify that any detail or glazing material is appropriate for the application.

Structural Glazing: When IG units are used in a structural glazing application, it is the customer's responsibility to order glass with an adequate IG unit sightline to resist negative wind loads. Upon request, OBE will provide a sightline analysis following receipt of the project design loads and accurate glass take-off.

Safety Glazing Locations: It is the customer's responsibility to order the appropriate safety glazing material for locations requiring safety glazing based on the governing codes.

Safety Glazing Labeling: Any special labeling requirements of the glass products must be discussed with fabricating plant prior to making a glass quote request and clearly indicated on the purchase order.

Warranty: All warranties begin at the time of manufacture and are per the terms and conditions listed on the product warranty document. As the buyer from the glass manufacturer OBE will assign the manufacturer's warranty to our direct customer and facilitate any coated glass warranty claim. Sample warranties are available upon request.

Glass Breakage: OBE does not warrant or guarantee against glass breakage of any kind for any reason.

Meetings: OBE relies on its customers to attend meetings; and to report if there are concerns over installation procedures or unacceptable conditions. Specific request for OBE to attend meetings must be made through the sales representative and a determination will be made regarding its necessity.

Mockups/Samples: Mockups or samples are not intended to set quality standards for materials or workmanship. Quality standards are to be determined by the industry accepted guidelines and any mutually agreed written objective measurable criteria.

Material Compatibility: Compatibility of glazing materials is the responsibility of the glazing contractor.

Industry Standards and Guidelines

ASTM Standards:

- ASTM C1036 Standard Specification for Flat Glass
- ASTM C1048 Standard Specification for Heat Strengthened and Fully Tempered Flat Glass
- ASTM C1172 Standard Specification for Laminated Architectural Flat Glass
- ASTM C1376 Pyrolytic and Vacuum Deposition Coatings on Glass
- ASTM E2188 Standard Test Method for Insulating Glass Unit Performance
- ASTM E2189 Standard Test Method for Resistance to Fogging in Insulating Glass Units
- ASTM E2190 Standard Specification for Insulating Glass Unit Performance and Evaluation
- ASTM E1300 Standard practice for Determining Load Resistance of Glass in Buildings

Safety Glazing:

- ANSI Z97.1 American National Standard for Safety Glazing Material Used in Buildings – Safety Performance Specifications and Methods of Test
- CPSC 16 CFR 1201 Safety Standard for Architectural Glazing Materials

Industry Publication:

- GANA Glazing Manual
- GANA Engineering Standards Manual
- GANA Laminated Glazing Reference Manual
- NGA FB27-11 Guidelines for the appearance of Insulating Glass Unit Edges in Commercial Applications at the Time of Installation

- IGMA TM-3100 Voluntary Guidelines for the Identification of Visual Obstructions in the Air Space of Insulating Glass Units

Quality

Cut Edge Quality: Glass provided by OBE will meet the cut edge quality requirements of ASTM C1036.

PIB Movement: PIB may extend above the spacer 1/8” at the time of fabrication; further migration after installation may occur due to the atmospheric effects and glazing conditions and is not considered a defect or cause for rejection.

Glass Color: Coated glass will meet the requirements of ASTM C1376, which allows a color variation of 4 Delta E and does not guarantee the color to be within the same quadrant of the natural axis. OBE does not guarantee the coated glass will have no variation in color and reflectivity to the naked eye under all lighting conditions.

Color Measurements: Specific requirements for glass color measurement criteria must be requested in writing with the written request for quote (RFQ)

Single Batch Glass Run: OBE cannot assure that all glass will be fabricated from a single batch run or from a single manufacturer. All coated glass will be from the same glass manufacturer.

IGU Spacer Construction: OBE will provide its typical spacer construction as passing the IGCC program testing to the ASTM E2190 test method for seal durability. Specific materials required for IG unit construction, such as the spacer material, must be indicated on the written RFQ and clearly indicated on the purchase order.

Glazing Schedule: OBE supplies glass products as ordered. It is the customer’s responsibility to confirm any deviation from the project specifications (including thermal performance and IG components) has been approved by the architect in writing prior to placing the glass purchase order.

Roll-wave distortion parallel to bottom edge of glass as installed...: Any heat-treated glass with a width (sill) dimension wider than the glass fabrication oven will have a vertical roll wave distortion pattern. Please contact the fabricating plant to determine what widths will have a vertical pattern.

Heat-Soak Testing: Specific requirements for heat-soak testing, reporting, and/or traceability must be indicated on the written RFQ and clearly indicated on the glass purchase order.

Strain Pattern / Quench Marks / Iridescence / Anisotropy: a strain pattern, also known as iridescence or anisotropy, is inherent in all heat-strengthened and fully tempered glass. This strain pattern may become more visible under certain lighting conditions. It is a characteristic of heat-treated glass and should not be mistaken as a discoloration, non-uniform tint or color, or a defect in the glass. The strain pattern does not affect any physical properties or performance values of the glass.

Maximum P/V Roll Wave: Specific roll wave criteria must be requested on the RFQ and accepted by fabricating plant in the written quote. Glass sizes of a height dimension less than 33" do not contain a sufficient middle area for a PVM measurement.

Millidiopter: Specific requirements for millidiopter measurements must be requested on the RFQ.

Bow: OBE produces heat-treated glass meeting the bow requirements of ASTM C1048.

Heat-Strengthened Surface Stress: OBE produces heat-strengthened glass in accordance with the surface compressive stress requirements of ASTM C1048, which is a range of 3500 - 7500 psi for glass with a thickness of 1/4" and less. The customer should discuss the surface compressive stress requirements for glass greater than 1/4" thick with the fabricating plant and document on the RFQ.

Argon Fill: OBE provides argon-filled units with an initial average fill rate of 90% or more. OBE makes no guarantees regarding the argon leakage rate.

Argon Filled – Holes & Plugs: OBE will provide its typical gas-filled IG units using construction and methods as passing the IGCC program to the ASTM E2190 test method for seal durability, which may include holes and plugs in the IG unit spacer.

Edge treatment: Heat-treated glass is provided with seamed edges, while annealed glass is typically provided with a factory cut edge that is unseamed. Specific requirements for edge fabrication must be documented on the RFQ and clearly indicated on the purchase order.

QA/QC Documentation: Specific requirements for QA/QC documentation must be documented on the RFQ.

IG unit thickness: Specific requirements for overall IG unit thickness and thickness tolerances must be documented on the RFQ.

Installation

Elastomeric/Neoprene Setting Blocks / Edge Blocks: Some elastomeric materials have shown incompatibility to insulating glass unit secondary silicone sealants and laminated glass interlayer materials. Silicone, and silicone compatible materials, are to be used with silicone dual-seal insulating glass units. Compatibility of glazing materials is the responsibility of the glazing contractor.

Field Surveillance: OBE does not offer field surveillance.

Site inspections: Specific request for OBE site inspections must be made through the sales representative and a determination will be made regarding its necessity.

Jobsite Protection: Specific shipping and packaging requirements must be discussed with the fabricating plant prior to making a glass quote request and clearly indicated on the purchase order.

Glass Technical Paper **FB01-00 (2023)**

Proper Procedures for Cleaning Architectural Glass Products

Architectural glass products play a major role in the comfort of the living and working environment of today's homes and commercial office spaces by providing natural daylight, views of the surroundings, thermal comfort and design aesthetics. Glass usage and condition often affect our selection of where we live, work, shop, play and seek education. This document describes procedures that generally apply to most architectural glass products. Certain glass types may require different procedures and care. Glass can be clear or tinted and have pyrolytic or sputtered Low-E or reflective coatings, some of which may be on the exposed surface of the glass. Glass products can be monolithic (single lites), laminated glass or insulating glass units. (See Glass Technical Paper FB15-07 Describing Architectural Glass Constructions). Glass can be of various strengths, i.e., annealed, heat-strengthened or fully tempered. There are also other decorative and functional glass types including spandrel, silk- screened, patterned, acid etched, and sandblasted. There may also be exposed films applied to the interior glass surface, for example security or spall films.

Architectural glass products should be properly cleaned and protected throughout the construction process using a program of regularly scheduled maintenance designed to maintain visual clarity and prevent glass surface damage. Since glass products can be permanently damaged if infrequently or improperly cleaned, glass producers and fabricators recommend strict compliance with the following procedures for cleaning glass surfaces.

Routine Cleaning & Maintenance

For routine maintenance, interior and exterior glass surfaces should be thoroughly cleaned as dirt and residue appear. Cleaning frequencies should be tailored to the individual characteristics inherent to the site conditions, as well as the severity of local environmental factors and atmospheric pollutants that vary from region to region. Before proceeding with cleaning, determine whether the glass is clear, tinted or reflective. Surface damage is more noticeable on reflective glass as compared with the other glass products. If the reflective surface is exposed, either on the exterior or interior surface, special care must be taken when cleaning, as damage to the reflective glass surface may result in coating removal and a visible change in light transmittance which is very noticeable. A simple test to determine the location of the reflective coating is to touch the point of a pencil to the glass surface. If the reflection of the pencil point meets the real pencil, the coating is exposed on that side. If there is a gap between the pencil point and the reflections, the coating is not exposed on that side of the glass. Cleaning tinted and reflective glass surfaces in direct sunlight should be avoided, as the surface temperature may be too hot for optimum cleaning. Exterior cleaning should begin at the top of the building and continue to the lower levels to reduce the risk of leaving residue and cleaning solution on glass that has already been cleaned. Cleaning procedures should also include checking that the wind is not blowing the cleaning solution and residue onto already cleaned glass.

Prior to beginning a cleaning project, it is strongly recommended that window cleaners test clean a small area of one window, then stop and examine the surface carefully for any damage to the glass and/or any exposed coating. The ability to detect certain surface damage, such as light scratches, may vary greatly with the lighting conditions. Daylight conditions are needed to properly evaluate a glass surface for damage. Scratches that are not easily seen with a dark or gray sky may be very noticeable when the sun is at a certain angle in the sky or when the sun is low in the sky. In addition, because different backgrounds may yield different observations, cleaning methods should be tested on all glass constructions on the building, including both vision and spandrel units.

Cleaning should begin by soaking the glass surfaces with clean water and a mild, non-abrasive glass cleaning solution. Glass cleaning solutions should not include acids, especially muriatic / hydrochloric and Hydroflouric. Apply generous amounts of solution to the glass surfaces with a brush, strip washer or other non-abrasive applicator, and lightly agitate to loosen the soil and debris. Immediately following the application of the cleaning solution, a window cleaning squeegee should be used to remove all of the cleaning solution from the glass surface. During routine cleaning care should be taken to avoid metal contact with the glass surface; razor blades and metal scrapers should not be part of routine cleaning. The use of sufficient water will help prevent abrasive particles from being trapped between the glass and the cleaning tools being used. However, the window cleaner needs to be diligent in keeping all abrasive particles from scratching the glass.

The International Window Cleaning Association (IWCA) recognizes an additional glass cleaning technique being utilized by some professional window cleaning contractors. This technique employs the use of pure water delivered to the glass surface using a specialized extension pole. Gentle agitation with a non-scratching (non-abrasive) brush is followed by the final pure water rinse. Rinse water is generally allowed to evaporate from freshly cleaned surfaces. Therefore, the pure water used in both the wash and rinse must have a total dissolved solids content (TDS) of 20 parts per million (PPM) or less to prevent spotting and streaking of cleansed surfaces. The use of tap water is not acceptable. Effective water treatment, via ion exchange and/or reverse osmosis equipment should be used in conjunction with delivery & rinse methods at all times. Water quality can be monitored with a handheld TDS or conductivity meter. A reading of 40 micro-Siemens/cm (0.025 Me ohm – cm) represents a TDS level of 20 PPM.

Non-Routine Post-Construction Cleaning & Restoration

Careful communication between the responsible parties should precede the use of aggressive cleaning techniques, as any non-routine cleaning carries a risk of irreparable damage to glass products.

During all stages of construction, the glass must be properly protected from construction debris such as cement, paint, varnish, adhesives and other construction material commonly found on job sites. (See the NGA/IWCA Bulletin FB03-03 Construction Site Protection and Maintenance of Architectural Glass). Extended construction schedules may create the need for multiple cleanings to avoid the accumulation of significant amounts of soil and debris, and to avoid potential damage. In addition to ordinary techniques for protection from construction debris used by various trades, temporary protective window films may be applied to glass. Follow specific manufacturer instructions regarding film application and removal. If the film is removed prior to job completion, additional cleanings may still be needed to prevent glass damage. Failure to remove temporary protective films by the manufacturer's recommended date may result in aggressive methods being required to remove the film.

Glass that is improperly stored or left unprotected during construction may result in glass that cannot be successfully cleaned using routine cleaning procedures. In such situations, more aggressive cleaning and restoration techniques may become necessary, such as the use of razor blades, chemical cleaning and/or mechanical polishing. Glass surface conditions that may require more aggressive cleaning techniques would include, but not be limited to, the accumulation of paint, stain or varnish overspray; mortar, concrete or cement splashing on glass; silicone sealants and/or lubricants being smeared or sprayed onto glass and frames; and sealer overspray or run-off from adjacent masonry or stone waterproofing operations. In the process of removing tenacious contaminates from unprotected glass, particles may be trapped between the razor blade and the glass, resulting in fine scratches.

While members of NGA neither condone nor recommend scraping of glass surfaces with blades or scrapers for routine cleaning, it is recognized that window cleaners may choose more aggressive techniques, including the use of razor blades, in non-routine cleaning. In such cases, use of razor blades should be limited to the affected areas of the glass. Scraping should be done in one direction only with a new blade. Never scrape in a back and forth motion as this could trap particles under the blade that may cause scratches. These scratches may be visible at all times, but in some cases they may be visible only under certain lighting conditions. Significant care should be taken to ensure the glass is not scratched. Razor blades should never be used on coated glass surfaces. Contact a professional window cleaner proficient in construction window cleaning, such as a member of the IWCA for the most appropriate solution.

Glass Types

When cleaning the glass in architectural windows and doors, it is necessary to determine what type of glass is being cleaned and what, if any, type of coatings may be present on the exposed surfaces. In addition to reviewing the bulletins previously referenced, it is important to review Glass Technical Paper FB02-02 *Heat-Treated Glass Surfaces are Different* before initiating the window cleaning process, as glass may be heat-treated, i.e., heat-strengthened or fully tempered. Heat-treated glass is used in most architectural glass products today for a variety of strength and safety reasons, but it must be understood that heat-treated surfaces require greater care when cleaning as discussed in detail in the above referenced bulletin. The use of razor blades should be the last possible option, especially on heat treated glass.

Some glass may contain a logo that may indicate the glass supplier and if the glass is tempered, heat- strengthened or laminated, but it typically will not indicate the glass type or if exposed coatings are present. A logo may not be visible or present on all heat-treated glass products, so the lack of a logo does not mean the glass is not heat-treated.

High performance windows may be produced with a coating on one or both exposed surfaces. Low-E coatings are typically neutral in color and very difficult to see. Reflective coatings increase the reflectivity of the glass and are normally obvious. Specific glass cleaning procedures must be adhered to when attempting to clean coated glass surfaces. Consult the glass manufacturer's guidelines for specific procedures.

Decorative glass may have unique cleaning requirements. Refer to FB19-08 *Guidelines for Handling and Cleaning Decorative Glass* prior to cleaning decorative glass.

The plastic interlayer in laminated glass is generally exposed around the periphery of the window glass; cleaning fluids and their vapors must be kept away from this area. For cleaning laminated glass, or windows and doors containing laminated glass, do not use anything that is corrosive such as solvents, acids, bases or other chemicals. Examples of some materials that may cause harm include, but are not limited to:

Bleach (or other solutions containing sodium hypochlorite)

Acids, especially muriatic/hydrochloric and hydrofluoric (often found in glass cleaning and restoration products)
Ammonia
Toluene
Xylene
Methyl Ethyl Ketone (a.k.a. MEK)
Acetone

Ethyl Acetate
Mineral Spirits
Turpentine
Methanol
Products with labeling that states they are flammable or corrosive

Contact the laminated glass supplier or interlayer manufacturers for additional recommendations and cautions.

For glass with window film applied to the surface, care must be taken not to scratch the film. Do not use bristle brushes or abrasive cleaning materials. A soft cloth or clean synthetic sponge is recommended for washing. Paper towels or newspapers are not recommended. Do not rub vigorously or use heavy pressure in the cleaning process. Mild detergent or household window cleaning solutions are recommended for cleaning window films. Cleaning solutions containing ammonia may not be suitable for all film types; check with the film supplier for recommended cleaners. Additional caution is recommended when cleaning spliced areas of film. Clean in the direction of the splice.

Insulating glass, laminated glass and decorative glass is glazed in many ways, utilizing glazing sealants, gaskets, and/or tapes. Glazing materials do not provide a sufficient barrier to prevent cleaning agents from entering the glazing pocket and damaging the edge of the glass product or affecting the insulating glass unit seal. The presence of weep holes is recommended but is also not sufficient to overcome the risk of improper cleaning materials coming in contact with the edge of glass products. Exposure to certain chemicals may affect the sealants of insulating glass units and the surface of decorative products. Insulating glass unit longevity may be negatively affected by exposure to certain chemicals. Contact the supplier for additional recommendations and cautions.

The glass industry takes extreme care to avoid glass scratches by protecting glass surfaces during manufacturing and fabrication, as well as during all shipping and handling required to deliver the glass to the end user. A large percentage of damaged glass results from non-glass trades working near glass. They may inadvertently lean tools against the glass, splash materials onto the glass and/or clean the glass incorrectly, any of which can permanently damage glass.

To ensure long-term performance of the glass in a building, NGA and IWCA encourage glazing contractors, general contractors, building management and owners to be diligent in preserving the integrity of glass products. It is important to be aware of conditions that can lead to glass damage, to follow the handling and cleaning guidelines provided by NGA/IWCA and the glass fabricator, and to adhere to a regular schedule of maintenance cleaning. Generally, twice per year cleaning is sufficient; however, specific regions may require more frequent cleaning due to environmental factors and atmospheric pollutants. Contact a professional window cleaner, such as members of the IWCA, to discuss recommended frequencies for your particular building.

Quick-Reference Guide to Cleaning Architectural Glass Products

The following “Do’s” and “Don’ts” are offered as a supplement to this guide:

The following are things to DO:

- DO clean glass when dirt and residue appear
- DO protect glass during all stages of construction
- DO determine if coated glass surfaces are exposed
- DO exercise special care when cleaning coated glass surfaces
- DO avoid cleaning tinted and coated glass surfaces in direct sunlight
- DO start cleaning at the top of the building and continue to lower levels

- DO soak the glass surface with a clean water and soap solution to loosen dirt and debris
- DO use a mild, non-abrasive commercial window cleaning solution
- DO use a window cleaning squeegee to remove all of the cleaning solution
- DO clean one representative window and check to see if procedures have caused any damage
- DO be aware of and follow the glass supplier's specific cleaning recommendation
- DO caution other trades against allowing other materials to contact the glass
- DO watch for and prevent conditions that can damage the glass
- DO read the following Glass Technical Papers before cleaning any heat- strengthened or tempered glass products:
    - FB15-07 Describing Architectural Glass Constructions
    - FB02-02 Heat-Treated Glass Surfaces are Difference
    - FB03-03 Construction Site Protection and Maintenance of Architectural Glass (in collaboration with IWCA)
    - FB19-08 Guidelines for Handling and Cleaning Decorative Glass

The following are things NOT to do:

- DO NOT start cleaning without reading:
    - FB15-07 Describing Architectural Glass Constructions
    - FB02-02 Heat-Treated Glass Surfaces are Difference
    - FB03-03 Construction Site Protection and Maintenance of Architectural Glass (in collaboration with IWCA)
    - FB19-08 Guidelines for Handling and Cleaning Decorative Glass
- DO NOT allow dirt and residue to remain on glass for an extended period of time
- DO NOT begin cleaning glass without knowing if a coated surface is exposed
- DO NOT clean tinted or coated glass in direct sunlight
- DO NOT allow water or cleaning residue to remain on the glass or adjacent materials
- DO NOT begin cleaning without rinsing excessive dirt and debris
- DO NOT use abrasive cleaning solutions or materials for maintenance cleaning
- DO NOT ever use razor blades on coated glass surfaces
- DO NOT allow metal parts of cleaning equipment to contact the glass
- DO NOT trap abrasive particles between the cleaning materials and the glass surface
- DO NOT allow other trades to lean tools or materials against the glass surface
- DO NOT allow splashed materials to dry on the glass surface

Visit www.glass.org/store for a complete list of Glass Technical Papers, as well as other glass building products and glazing industry reference materials.

This Paper was developed by dedicated member volunteers and subject matter experts. The original version of this document was approved and published in 2000. This version of the document was updated and published in December 2023.

Heat-Treated Glass Surfaces are Different

Industry Cleaning Procedures to be Followed to Avoid Glass Damage

Heat-treated glass (fully tempered and heat-strengthened) has been in use for many decades. The demand for fully tempered glass increased greatly with the passing of safety glazing legislation in 1977. Heat-treated glass usage has increased in recent years for a variety of reasons including, but not limited to, changes to the building codes requiring safety glazing in more applications, the need to meet higher thermal stress loads due to the use of more high-performance glasses and coatings with increased heat absorbing and/or reflecting properties, the use of larger glass sizes, and increased design loads.

Currently, there are two types of heat-treated glass as defined in the ASTM International standard C1048 *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass.* The two types are heat-strengthened (Kind HS) and fully tempered (Kind FT). Both types of glass are produced using the same equipment. The majority of the heat-treated glass produced over the last 40 plus years has been done in horizontal roller hearth ovens using either a batch or continuous process. To prepare annealed glass for the heat-treatment process it is cut to the required final size, the edges are treated according to the specified finish (commonly seamed or polished) and the glass is washed. The glass is then transported on horizontal rollers through an oven where it is heated to approximately 1150°F (621°C). Upon exiting the oven, the glass is rapidly cooled (quenched) by blowing air uniformly onto both surfaces simultaneously. The cooling process leaves the surfaces of the glass in a state of compression, and the central core in compensating tension.

The color, clarity, chemical composition, light transmission, hardness, specific gravity, expansion coefficient, softening point, thermal conductivity, solar optical properties and stiffness remain unchanged by the heat-treating process. The only properties that change are improved flexural and tensile strength, and improved resistance to thermal stresses and thermal shock. Under uniform loading, heat-treated glass is stronger than annealed glass of the same size and thickness. The heat-treating process will change the break pattern of glass that has been treated to a higher level of compressive stress, i.e. fully tempered glass that is designed to meet the industry safety glazing standards will break into relatively small pieces, thereby greatly reducing the likelihood of serious cutting or piercing injuries.

As mentioned, the heat-treating process typically involves the transport of very hot glass on rollers. As a result of this soft glass-to-roller contact, some glass surface changes will occur. Minute glass particles (fines) from the glass cutting, edging and washing processes, typical manufacturing plant air-borne debris or dust, refractory particles from the tempering oven roof, as well as external airborne dirt and grit carried into the plant by the large volumes of quench air used in the process, may adhere to one or both glass surfaces. Also, the physical contact of the soft glass surface with the rollers may result in a marking or dimpling of the glass surface.

Current glass quality specifications contained in ASTM C1036 *Standard Specification for Flat Glass*, establish the size and number of glass imperfections allowed based on specific visual inspection criteria. The glass surface conditions listed above are not usually visible to the eye under normal viewing. These surface conditions do not threaten the visual nor structural integrity of the product and are not reason for rejection of glass based on the industry ASTM consensus standards.

However, despite being invisible, such surface conditions may be detectable to the touch. This difference in "feel", between annealed and heat-treated glass, can lead to issues during cleaning of the glass, as glass cleaning workers attempt to remove microscopic particles. With the best of intentions, they may attempt to scrape particles that can be felt, but not seen, and very often end up scratching and chipping the glass surface.

Additionally, once the glass is delivered to the construction site and/or installed, construction materials and debris may be deposited onto the glass surface. Paint, stucco, concrete, adhesives, and other materials may be splattered on the glass and left for long periods of time. These materials and the methods for removing them may also damage the glass surface.

It is important to note that the recommended cleaning procedures for heat-treated glass are the same as for annealed glass. The use of scrapers, abrasives, and harsh chemical cleaning agents are not recommended for any glass product because they can cause irreparable damage. Despite the best intentions, window cleaners, and other tradesmen, may attempt to remove construction dirt and debris from the glass surface by scraping the surface. This can lead to glass damage, such as scratching and chipping, if any microscopic particles that are adhered to the surface become dislodged and are transported across the glass surface during the scraping process.

Acceptable cleaning procedures may be available from glass manufacturers and fabricators. In addition, the National Glass Association (NGA), with the International Window Cleaners Association (IWCA), have published Glass Technical Papers that may be referenced. *Proper Procedures for Cleaning Architectural Glass Products* includes industry recommended cleaning procedures as well as a list of Do's and Do Not's. *Construction Site Protection and Maintenance of Architectural Glass* addresses steps to avoid permanent damage to glass.

Heat-treated glass products are critical components of today's high-performance coated, insulating, laminated, spandrel, safety glazing, bullet-resistant, blast-resistant, and hurricane-resistant fenestration products. Millions of square feet of installed heat-treated glass have provided trouble-free performance since the 1960s. Continued use of acceptable cleaning practices will minimize the risk of glass damage and enable the glass to maintain its original attractive appearance for years to come.

Visit www.glass.org/store for a complete list of Glass Technical Papers, as well as other glass building products and glazing industry reference materials.

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NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB03-03 (2023)**

Construction Site Protection and Maintenance of Architectural Glass

Steps Must Be Taken to Avoid Permanent Damage to Glass

Architectural glass products used in windows, doors and skylights for today's residential and commercial building projects are more sophisticated than those used in earlier fenestration applications. Performance requirements call for glass to be coated and used in an insulating glass unit in order to be more energy efficient; and often heat-treated and laminated to provide greater strength, safety, and security. As a result of increased performance capabilities, more high-performance glass is being used in both residential and commercial construction. The higher valued products and their greater susceptibility to damage have increased the importance of proper site storage, handling, installation and protection throughout the construction process.

During glass manufacturing, fabrication and installation, products are carefully handled to prevent surface and edge damage. Materials are packaged to provide protection during shipment and delivery. Once finished materials are placed on a construction site, they become exposed to a variety of conditions and influences that can adversely affect product aesthetics and functionality. Irreparable glass damage can occur from improper storage and handling, exposure to chemicals and leaching agents, prolonged exposure to moisture, mechanical attack and breakage, damage related to adjacent construction activities and improper cleaning methods.

Site Delivery and Storage

Windows, doors and skylights for residential construction typically arrive on construction sites preglazed, while commercial construction applications often require glass be delivered to the site and glazed at a later date.

In both types of construction, it is vital that materials be properly stored for the duration of the construction process. The complex nature of construction projects and site management requires well-planned and executed material delivery and storage. The following is a list of recommended practices that glazing subcontractors should observe for site delivery and storage of fenestration materials:

- Consult glass and glazing system suppliers for specific recommendations on the site storage, handling, installation, and protection of their materials before any work is started.
- Coordinate glass deliveries, to the extent practical, to minimize on-site storage durations.
- Work with the general contractor or builder to select on-site under-roof storage locations that avoid direct rain and water runoff, work areas of other trades, and areas of high traffic and to minimize material movement and handling.
- Secure, block, and brace individual cases of glass and preglazed materials to prevent falls.

- Ensure blocks or supports keep the bottom edge of materials well above potential puddles of rainwater or other conditions that could cause damage.
- Provide secure, temporary covering that prevents direct water flow, but ensures ventilation and combats condensation buildup on the glass.
- Clearly mark storage areas of glass cases and preglazed materials using colored ribbons or tape.
- Ensure that glazing components held in storage are not subjected to deposits from concrete and masonry building materials or hard water spotting from various sources of tap water at the job site.
- Ensure that stored materials are not exposed to activities of other trades such as welding, painting, insulating, and fireproofing.
- Establish a program for daily inspection of stored glass and glazing systems to monitor conditions and ensure prompt corrective action when needed.
- Follow manufacturer's guidelines when using temporary protection films.
- Do not allow protective films to remain on the surface beyond their useful life, as removal methods may damage certain types of glass and/or their coatings.
- Do not expose open packs of glass to direct sunlight as the insulating effects of the glass layers may increase the thermal stress in the glass and may result in glass breakage.

Trade Awareness

As fenestration materials are delivered to a residential or commercial construction site, it is recommended that the glazing subcontractor and window cleaner contact the general contractor (in person and follow up in writing) to let him know how important it is that he make all construction trades aware of the potential for permanent damage and their level of responsibility in the event materials are subjected to harmful conditions. In the event of damage, prompt action is required to minimize further damage.

Site Handling and Installation

Glass and glazing system manufacturer's recommendations for site handling and installation procedures should be followed. Residential and light commercial windows, doors, and skylights should be installed in accordance with ASTM International document E 2112 – Standard Practice for Installation of Exterior Windows, Doors and Skylights. Glass for commercial glazing applications should be handled and installed in accordance with guidelines set forth in NGA's GANA Glazing Manual.

Post Installation Inspection and Protection

After installation, special attention by all trades should be given to construction activities in order to prevent exposure of glass in windows, doors and skylights to weld splatter, paint, plaster, sealants, fireproofing, and alkali and chemical attack. The subcontractor, general contractor, or builder should inspect and document the condition of the glazed materials on a daily basis.

At this stage of construction, the glazing subcontractor should request, in writing, that the general contractor or builder remind other construction trades of the potential for irreparable damage to the glazed materials and to implement systems and procedures for protection. The following is a list of common conditions and causes that damage glass after installation:

Condition	Cause
Glass surface corrosion often characterized by permanent iridescent or white haze surface staining	Glass got wet during storage due to reasons such as, but not limited to, being stored outside uncovered, or extended storage with inadequate ventilation and/or improper glass separation
Glass surface or edge damage	Inadequate on-site protection; ill-advised or vulnerable storage locations; exposure to other trades
Chemical attack, surface pitting and hard-to-clean deposits	Overspray and runoff of chemicals from sealing/cleaning of concrete, masonry, roofing, etc; inadequate protection and/or poor storage location
Weld-splatter surface damage and reduction in glass strength	Location of glass near welding; inadequate protection of stored or installed glass
Stubborn, tenacious surface deposits from concrete and masonry runoff, as well as hard water spotting	Poor storage and/or protection of uninstalled glass; absence of prompt, interim cleaning of installed glass during construction

Construction Clean-Up

If glass is exposed to harmful materials or conditions during construction, the general contractor or builder and the trade involved, if known, should be immediately advised by the glazing contractor of the potential damage. In the event that damage has already occurred, the glazing contractor and glass fabricator/supplier should be consulted to assess damage, take corrective actions, and mitigate the potential for future damage.

Deep surface scratches, contact by hot weld-splatter and edge damage threaten the structural integrity of glass and may require glass replacement. Surface contact with harmful materials will require prompt cleaning by professional window cleaners, such as members of the International Window Cleaners Association (IWCA).

If harmful exposure results in conditions that cannot be cleaned using typical glass cleaning procedures, a professional window cleaner should be consulted for recommendations on more aggressive glass cleaning procedures. The use of a more aggressive procedure may itself damage the glass. Careful thought and discussion must precede the use of aggressive cleaning procedures.

The general contractor or builder may need to schedule periodic glass cleaning during the construction process. Extended construction schedules and site conditions often result in dirt and debris build-up. Professional cleaning at the initial signs of build-up can decrease the potential for glass damage. Refer to FB01-00 *Proper Procedures for Cleaning Architectural Glass* for further information.

Long-Term Building Maintenance & Performance

Following the completion of the construction project and throughout the life of the building, windows, doors, and skylights should be properly cleaned. Building facades may be exposed to sealant rundown, pollutants, dirt and debris, which can attack and damage glass surfaces over time. Building maintenance schedules should include frequent cleaning to ensure long-term glass aesthetics and performance. Cleaning frequencies should be tailored to the individual characteristics inherent to these conditions as well as the severity of local environmental factors such as acid rain and atmospheric pollutants that vary from region to region.

Building owners should ensure that individuals cleaning fenestration materials are well aware of the glazing products in the building and their unique properties and are knowledgeable about and capable of using proper cleaning procedures and practices recommended by the glazing manufacturer and the glass industry.

Proper protection of glass in windows, doors, and skylights throughout the construction process and the life of a building are essential. Planning and execution of the practices described and recommended in this Paper will enable the glass to meet the aesthetic and performance expectations and the needs of the building occupants.

Visit www.glass.org/store for a complete list of Glass Technical Papers, as well as other glazing and glass building products industry reference materials. Most Glass Technical Papers are available free of charge to NGA members and for a small fee to nonmembers.

This Paper was developed by dedicated member volunteers and subject matter experts. The original version of this document was approved and published in 2003. This version of the document was updated and published in April 2023.

Glass Technical Paper FB13-07 (2018)

The Importance of Fabrication Prior to Heat-Treatment

Glass applications frequently require a variety of glass edge and/or surface fabrication. Some common fabrication processes include: edge seaming, grinding, polishing, hole-drilling, notch-cutting, surface-grooving, sand-blasting, and etching. The Glass Association of North America (GANA) does not recommend glass fabrication after heat-treatment because it may weaken the glass and/or cause it to break. This recommendation is confirmed in Section 7 of ASTM C 1048, Standard Specification for Heat-Treated Flat Glass-Kind HS, Kind FT Coated and Uncoated Glass, which states, “All fabrication, such as cutting to overall dimensions, edgework, drilled holes, notching, grinding, sandblasting, and etching, shall be performed before heat-strengthening or tempering and shall be as specified.”

The Heat-Treating Process

In order to provide greater resistance to thermal and mechanical stresses, and to achieve required break patterns for safety glazing applications, annealed float glass and patterned glass can be strengthened through a thermal process known as heat-treating. The most commonly used process for heat-treating architectural products calls for glass to be cut to the desired size and shape, and edges prepared to the specified condition. The glass is washed and then transported through a tempering furnace where it is uniformly heated to approximately 1150 °F (621 °C). Upon exiting the furnace, the glass is rapidly cooled (quenched) by blowing air onto all surfaces simultaneously.

The cooling process places the surfaces of the heat-treated glass into a state of high compression and the central core in tension. As shown in Figure 1, each surface compression zone is approximately 20% of the glass thickness and the middle 60 % of the glass thickness is the tension zone.

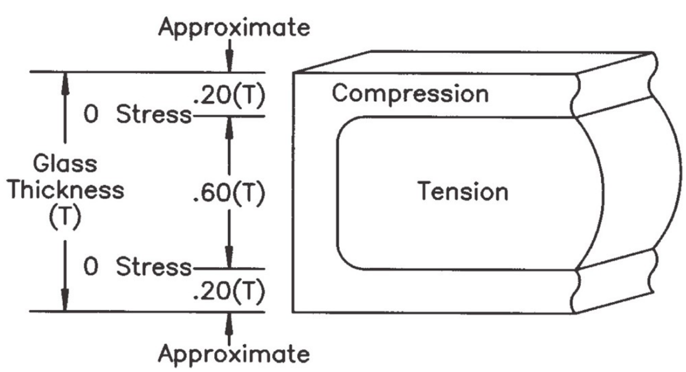

Figure 1
Heat-Treated Glass Compression and Tension Zones

Alteration of Surface Stress - Brought About by Fabrication After the Heat-Treatment Process

Fabricating glass after it has been heat-treated, such as grinding, sandblasting or etching, may compromise the compression and tension zones of the glass resulting in a weaker or broken piece of glass. Cutting and drilling heat-treated glass will result in breakage. Compromising the surface compression zones of fully tempered glass may also negatively affect its ability to comply with the industry safety glazing standards.

Penetration of a surface compression layer is a cause of heat-strengthened and fully tempered glass breakage. For example, each compression layer in a lite of heat-treated glass is approximately 20% of the glass thickness, penetration can occur in as little as 0.025” (0.64 mm) for 1/8” (3 mm) thick glass and 0.040” (1.02 mm) for 1/4” (6 mm) thick glass.

Heat-treated glass can be further fabricated by any process that does not alter the surface compression layer such as sputtered (vacuum deposition) coatings onto the surface; assembly of laminates and insulating glass units; and adding films and coatings for opacification.

Heat-Treated Laminated Glass

Two or more lites of heat-treated glass can be laminated when glass retention after breakage is desired to meet performance or building code requirements. Typical applications include canopies, skylights, railings, glass floors, curtain wall and storefront systems. Unlike annealed laminates, heat-treated laminates cannot undergo additional fabrication after laminating.

Similar to monolithic heat-treated glass, ASTM C1172 *Standard Specification for Laminated Architectural Flat Glass* states, “All dimensional fabrication, such as cutting to overall dimensions, edgework, drilling, notching, grinding, sandblasting, and etching on laminates containing heat-strengthened, chemically strengthened, or fully tempered glass shall be performed prior to strengthening or tempering.”

In addition, ASTM C1172 gives length and width tolerances for rectangular shapes of symmetrically laminated glass including mismatch. These tolerances are shown below:

Laminate Thickness Designation, *t*	**Heat strengthened/Tempered Glass Tolerance**
t < ¼ in (6.4 mm)	+7/32 in, -3/32 in (+5.6mm – 2.4mm)
¼ in < ½ in (6.4mm< 12.7mm)	+1/4 in, -1/8 in (+6.4mm, -3.2mm)
½ in < 1 in (12.7mm < 25.4mm)	+5/16 in, - 1/8 in (+7.9mm, -3.2mm)

Most Glass Technical Papers are available free of charge. Visit www.glass.org/store for the complete list, as well as other flat glass industry reference materials.

This Paper was developed by dedicated member volunteers and subject matter experts. The original version of this document was approved and published in 2012. This edition of the paper was updated and published in 2018.

NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper FB04-03 (2021)

Design Considerations for Laminated Glazing Applications

Modern architectural designs often require glazing materials that provide enhanced levels of security and safety performance properties. These properties include resistance to ballistics, blast, hurricane/cyclic wind pressures and physical attack. Applications may also require desirable properties such as sound reduction, fade resistance, and solar & thermal control. Laminated glazing materials (see Figure 1 and Figure 4) consist of multiple plies of glass, interlayers, resins and/or plastic glazing materials (such as polycarbonate sheet or acrylic), which are often complex in nature. They are designed to provide specified levels of performance.

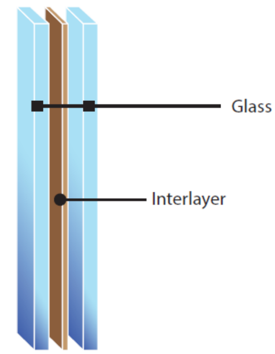

Figure 1: Basic laminated glass

Design professionals and building owners should be aware of the following considerations when selecting and specifying laminated glazing constructions:

Aesthetic Color

Commercial clear float glass is nearly colorless, however, a green or blue-green tint, which is faint in thin glass may become noticeable in glazing applications where the glass thickness exceeds 3/8” (10 mm). Laminated glazing materials, utilized for their impact resistance to ballistics, blast and physical attack and for additional applications such as zoo exhibits and large aquariums, incorporate numerous plies of transparent glazing materials. In these applications, the thickness of the glass portion of the laminate often results in a more apparent degree of green. In some instances, the green tint is not as pronounced, as it can be disguised by the blue color of the water or the color of painted walls in an aquarium. The green tint also may not be as apparent in certain constructions such as glass-clad polycarbonate laminates that contain more polycarbonate than glass.

However, in certain applications, the green tint may be regarded as aesthetically displeasing to a designer and owner. For those projects that require the highest level of color clarity, low-iron float glass should be considered (see Figure 2). Low-iron float glass may also assist the designer in providing a closer color match to a less thick glass that is in proximity to the laminated glazing.

Figure 2: Comparison of clear float glass and low iron glass

Many laminated glazing components are designed to block ultraviolet light (energy wavelengths from 280nm - 380nm); however, these components may also block a portion of the visible light spectrum (wavelengths from 380nm – 420 nm) with a result that there may be a slight yellow appearance. This yellow appearance may become noticeable when these materials are used in thicker or a greater number of multiple layers. In addition, yellowness can vary by interlayer type and manufacturer. This color should be considered in conjunction with color imparted by the glass itself.

There are also design considerations, which must be taken into account when a low-e or reflective coating is used in the construction of a laminate. When the coating, applied to the glass substrate, is placed in contact with the interlayer, the refractive index of the coating is changed and may result in a perceived color shift. This means that a coating in an IG unit may appear a different color than the same coating in a laminate.

Optical Distortion

<u>Heat-Treated Glass</u>

Images viewed in reflection from and by transmission through laminated glazing materials may be distorted (see Figure 3). Both reflected and transmitted optical distortion may result from heat-treatment of glass, thickness variability of the materials used, mechanical stresses applied by the framing system and changes in exterior wind pressure and interior building pressure.

Laminated glazing materials may incorporate multiple plies of heat-treated (e.g. heat-strengthened, tempered) glass in order to achieve high levels of resistance to thermally and mechanically applied loads. Bow (warp), roll wave distortion and picture frame distortion are inherent characteristics of heat-treated glass. While fabricators take steps to minimize these conditions, they cannot be eliminated. All of these characteristics are accentuated by the use of reflective coatings and tinted glass substrates.

Figure 3: Example of distortion

Since transmitted distortion is dependent on the overall thickness variability, it tends to be exaggerated by multiple plies of glass and other components, i.e., lens effect. The thickness variations of the individual plies are additive. Laminated constructions incorporating annealed glass typically exhibit less reflective and transmitted optical distortion. Distortion in all glazing materials may occur as a result of glazing system wind load pressures. Refer to ASTM C1172 *Standard Specification for Laminated Architectural Flat Glass* for allowable process blemishes, length and width tolerances, and maximum allowable overall bow.

The visibility of reflective distortion is greatly affected by surrounding conditions and glazing orientation. If the reflected image is a uniform blue sky, the reflective image that appears in the laminated product may appear without distortion. If the same laminate is reflecting multiple gridlines from an adjacent building, the reflection may appear distorted. Roll wave distortion may be more visible by reflectance and transmittance when the direction of the wave pattern is glazed parallel to the jamb or vertical dimension of a window or door. In this application, images of lineal objects (such as building walls, utility and flag poles) and moving objects (such as cars and aircraft) become more visible as the viewing angle changes. In order to decrease the visibility of roll wave distortion in heat-treated laminates, fabricators commonly recommend, and design professionals specify, that the wave direction (wave's peak) be glazed parallel to the sill of a window or door whenever possible. It is recommended that the manufacturer be notified in writing of these instructions prior to the onset of glass fabrication. Heat-treated glass fabrication equipment limitations may not allow roll wave orientation to the sill when the width dimension of a lite of glass exceeds the width of the heat-treating oven.

Multiple-Ply Laminates

Multiple-ply glazing materials (see Figure 4) that include non–glass components such as interlayer films and/or plastics sheet products such as polycarbonate, acrylic sheet or polyethylene terephthalate (PET), may also be a source of unwanted optical distortion. Special consideration should be given to these types of laminates.

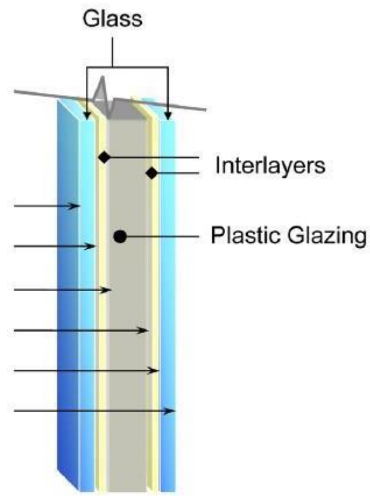

Figure 4: Example of multiple-ply laminate

Both glass (as previously described) and non-glass components may have thickness or flatness variability that creates lens or other visible effects, which may cause distortion of images when viewed through the glazing material. The magnitude and spacing of this variability are both important factors when trying to assess the suitability of a multiple-ply laminate for a given application as a precise alignment of the components containing this variability is not possible. This distortion is greatly affected by viewing angle, and vertical lens lines are generally more objectionable.

High performance plastic sheet used in multiple-ply laminates are most often either polycarbonate or acrylic sheet.

Acrylic sheet materials are produced by several processes, which exhibit varying degrees of distortion and thickness variations. Polycarbonate sheet is produced by an extrusion process, and therefore exhibits die lines (ripple direction) on both coated and uncoated polycarbonate, which may produce an objectionable distorted image. This distortion can be minimized by placing the ripple direction horizontal to the plane (when feasible). While plastic sheet manufacturers take steps to minimize these conditions, they cannot be eliminated.

Designers are recommended to further consider other conditions, such as:

- Thermal expansion/contraction properties and changes in humidity, which may cause the plastic glazing material or the interlayer to bow and/or warp
- Adequate space within framing systems to reduce perimeter issues due to edge pinch
- Localized areas of distortion resulting from small particulate inclusions (fish-eyes) on coated plastic sheet materials
- As more individual plastic layers are utilized in the laminate, distortion may become more pronounced.

Multiple-Ply Laminates incorporating both glass and polycarbonate components and their appropriate interlayer(s) are further described within ASTM C1349 *Standard Specification for Architectural Flat Glass Clad Polycarbonate*, and its Appendixes. Additional reference to the plastic sheet components and these types of laminates can also be found within the *GANA Glazing Manual* and the *GANA Laminated Glazing Reference Manual*. Refer to ASTM D4802 *Standard Specification for Poly (Methyl Methacrylate) Acrylic Plastic Sheet* for the methods by which acrylic plastic sheet is produced and other specifications.

Iridescence

When viewing laminated glazing constructions, under certain conditions, a pattern of iridescent spots or darkish shadows may become visible (see Figure 5). This is commonly referred to as the strain pattern/anisotropy of the heat-treated glass and is related to

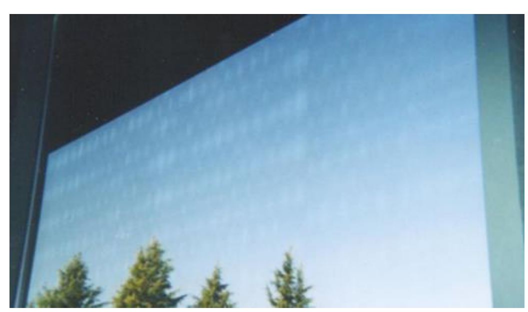

Figure 5: Example of iridescence

the stresses introduced in the cooling process of the glass fabrication. While not normally visible, the strain pattern may become more evident by reflectance and in transmittance when viewing the glazing material at severe angles or under polarized light conditions. The potential of the iridescence becoming more pronounced is enhanced as the thickness of the laminated glazing material increases. The strain pattern is inherent in those heat-treated components and is not a result of discoloration or non-uniformity.

Temperature Performance

Laminated glass may be used in applications where the laminate could be exposed to high and low temperatures. Examples are spandrel, tinted, southern-facing elevations, coatings, and non-conditioned space behind the glass. The performance of the interlayers at different temperatures varies by interlayer type. Consult the interlayer manufacturer for specific interlayer temperature limits.

Laminated glass, when properly laminated, will pass the Bake Test for 16 hours at 212°F (100 °C) in accordance with ASTM C1914 *Standard Test Method for Bake and Boil Testing of Laminated Glass*. Performance will vary with time and temperature above this limit and the laminate may visually show bubbles and/or slight yellowing, typically at or near the edge. Consult the interlayer manufacturer for specific interlayer temperature limits.

The glass strength charts presented in ASTM E1300 *Standard Practice for Determining Load Resistance of Glass in Buildings* assume an interlayer temperature of 122°F (50°C) when calculating the short duration load resistance and the center of glass (COG) deflection for laminates exposed to the specified wind loads. The shear relaxation modulus of interlayers changes with temperature and duration of load.

For more information on laminated glass and temperature capabilities and performance, refer to the NGA Laminated Glazing Reference Manual and consult with the interlayer manufacturer or supplier.

Product Awareness

As the design thickness of multiple plies of heat-treated glass and/or glass and plastic material increases to meet application requirements, the potential for distortion of images viewed through the glazing also increases. The bonding of multiple surfaces accentuates distortion as a result of the inherent variations in flatness of the component materials. Design professionals and building owners must be particularly aware of these characteristics in applications that involve viewing moving objects through the glass.

It is essential that design professionals consult with fabricators and suppliers in the early stages of design and engineering, given the sophisticated nature of laminated glazing materials required for optimum performance in safety, security, hazard resistant and sound reduction applications. Awareness of the laminated glazing product construction and inherent characteristics of the laminated glazing can dramatically affect the design application. Design professionals and building owners are strongly encouraged to utilize full-size mockups for evaluating the appearance of the glazing system under the specific project conditions, lighting conditions, and surrounding landscape. Utilization of a mockup is an inexpensive and reasonable process to ensure the product(s) and project design(s) meet a client’s expectations.

References

- ASTM C1172 Standard Specification for Laminated Architectural Flat Glass
- ASTM C1349 *Standard Specification for Architectural Flat Glass Clad Polycarbonate*- www.astm.org
- GANA Glazing Manual- https://www.glass.org/resources/publications/manuals
- GANA Laminated Glazing Reference Manual- https://www.glass.org/resources/publications/manuals
- ASTM D4802 *Standard Specification for Poly (Methyl Methacrylate) Acrylic Plastic Sheet*

Visit www.glass.org/store for a complete list of Glass Technical Papers, as well as other glazing and glass building products industry reference materials. Most Glass Technical Papers are available free of charge to NGA members and for a small fee to nonmembers.

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