

Product Standards

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This reference guide documents quality and product standards associated with Tristar Glass, Inc.'s fabrication of architectural flat glass. It contains, but is not limited to, information regarding the proper inspection of and associated tolerances for: flat, heat-treated, coated, and laminated glass. This document draws heavily from the ASTM standards C1036, C1048, C1172, and C1376, however, these documents should be referenced in full for a comprehensive listing of each standard.



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Product Standards





GLASS PRODUCTS

Tristar Glass, Inc. product standards are based on the following ASTM documents. Complete versions of these documents are subject to copyright and may only be obtained directly from ASTM (www.astm.org)

ASTM C-1036 – Standard Specification for Flat Glass

ASTM C-1048 – Standard Specification for Heat Strengthened and Fully Tempered Flat Glass

ASTM C-1172 – Standard Specification for Laminated Architectural Flat Glass

ASTM C-1376 – Standard Specification for Pyrolytic and Vacuum Deposition Coatings on Flat Glass

Introduction

High-precision automated machinery allows Tristar to maintain a strong balance between artisanal quality and computer-controlled speed of production. It should be noted, however, that the fabrication processes used to create Tristar's glass products often subject the glass to high temperatures, pressures, and sometimes a significant amount of handling between each process. While these processes are necessary to afford our glass products with additional strength, safety, or efficiency, they can be known to cause slight flaws in the surface of the glass that may be visible should the glass be overly scrutinized.

The above ASTM standards have been created to define official viewing conditions that determine the acceptable limits of these flaws, optically and aesthetically. These standards also address safety concerns, rejecting any such flaw that may cause the glass to break or fail.

All of Tristar Glass' quality and production standards are designed to meet or exceed those set forth by ASTM and in most cases are above the industry standard.



1120 Main Parkway • Catoosa, OK 74015 • tristarglass.com
866.655.1624 • 918.739.3611 • 918.739.3620 fax • 866.875.9513 toll free fax

Standard Specifications for Flat Glass

Monolithic Dimensional Tolerances

Tolerances for length, width, and squareness for rectangular and nonrectangular shapes shall be determined by the following table:

Glass Thickness	Length and width Tolerance		Diagonal Tolerance	
	Cut Size	Stock Sheet	Cut Size	Stock Sheet
3/32"-1/4"	1/16"	1/4"	5/64"	1/8"
5/16"	5/64"	1/4"	7/64"	1/4"
3/8"	3/32"	1/4"	1/8"	1/4"
1/2"	1/8"	1/4"	11/64"	3/8"

Table 1: dimensional tolerances for monolithic flat glass

Edge chips

The following criteria are **NOT ALLOWED**:

- Chip depth > 50% of glass thickness
- Chip width > glass thickness or 1/4in (whichever is greater)
- Chip length > 2x chip width

Any "V"-chips, v-shaped imperfections in the edge of the glass, found within a production lite will cause the entire lite to be rejected.



Blemishes in Monolithic Flat Glass

A blemish is an imperfection in the body or on the surface of the glass. Linear blemishes include scratches, rubs, and digs and may be straight or curved in nature. Point blemishes include crush (light pitting), knots (lumps), dirt, stones and gaseous inclusions (cat eye).

All visual blemish inspections shall be made with the naked eye viewing samples in the vertical position at a viewing angle of 90° to the specimen using daylight (without direct sunlight) or other uniform diffused background lighting that simulates daylight (minimum 1700 lux measured at the center of the glass).

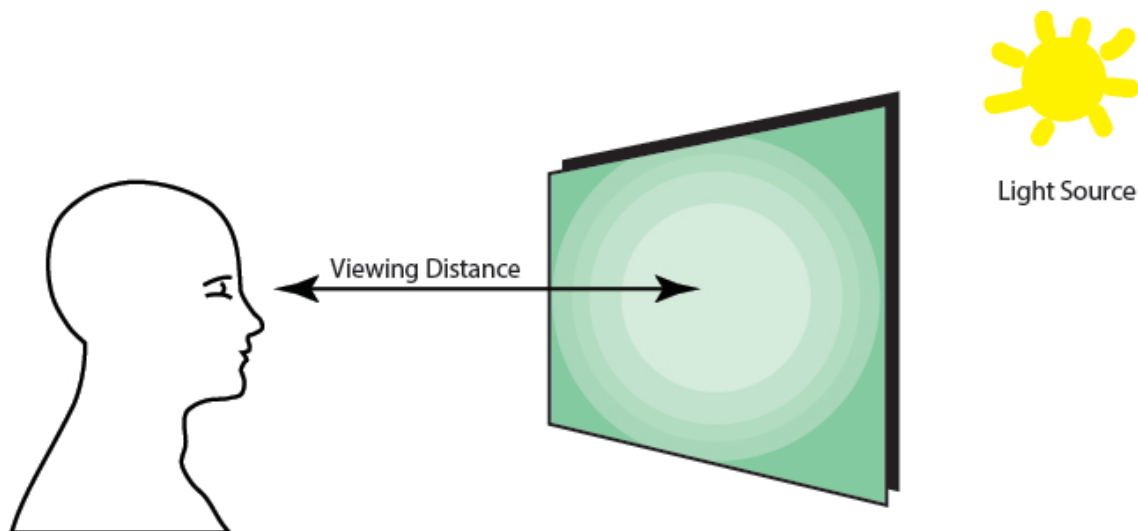


Figure 1: viewing in transmission

Linear blemish intensity shall be determined by detection distance. Detection distance is obtained viewing the specimen from a distance of 13 ft (4m) and progressing sequentially in, noting the distance at which the blemish is detected. Use the table on the following page to categorize a blemish and determine its acceptability.



Detection Distance	Blemish Intensity
132in (3.3m)	Heavy
39in (1m)	Medium
8in (.2m)	Light
< 8in (.2m)	Faint

Table 2: detection distance vs. blemish intensity

The following Line Blemishes are **NOT ALLOWED**:

- Multiple medium blemishes < 3 inches that are within 24 in of each other
- Medium blemishes > 3 inches
- Heavy blemishes

Point blemishes shall be viewed from a distance of **39in (1m)**. Point blemish size shall be determined by measuring the max length and max perpendicular width of the blemish and averaging the two dimensions.

The following point blemishes are **NOT ALLOWED**:

- Blemishes < .02in that form a detectable cluster at 6ft
- Multiple blemishes $\geq 0.05\text{in}$ < 0.06in within 24in* of each other
- Multiple blemishes $\geq 0.06\text{in}$ < 0.08in within 24in* of each other
- Blemishes $\geq 0.08\text{in}$

*Separation distances are specified for $\leq \frac{1}{4}$ " thick glass. Thicker glass may contain proportionally larger blemishes for the same 24in separation distance. Blemishes in size ranges that are allowed without separation distance criteria shall not be compared with those that have separation criteria. See applicable ASTM standard for pattern glass products.



Reflective or Low-E Coated Glass

Coating Blemishes:

The glass shall be inspected, in transmission ([see figure 1](#)), at a distance of 10ft (3.0 m) at a viewing angle of 90° to the specimen against a bright uniform background. If a blemish is readily apparent under these viewing conditions, the following criteria are NOT ALLOWED:

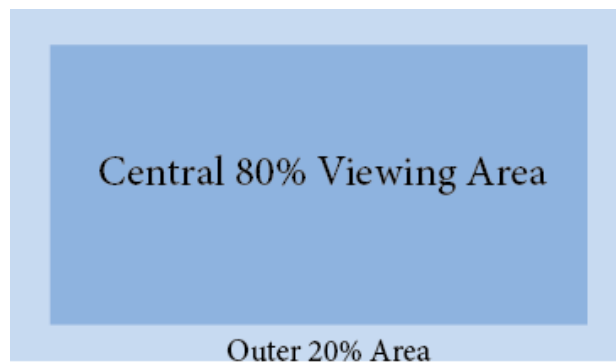


Figure 2: viewing area

- Pinholes > 1/16" in diameter in the central 80% of the viewing area
- Pinholes > 3/32" in diameter in the outer 20% of the glass area
- More than 2 readily apparent blemishes w/in a 3" diameter circle
- More than 5 readily apparent blemishes w/in a 12" diameter circle
- Scratches > 2" in the central 80% viewing area
- Scratches > 3" in the outer 20% viewing area
- Concentrated scratches or abraded areas

Coating Uniformity and Color Variation:

Visual observations of color differences on the exterior of a building are subjective and vary from person to person. Perceived color variation can be the result of lighting conditions (both internal and external), distance and angle of observation, and the surrounding area.



Tristar's glass products conform to industry color standards. Variations in color and uniformity from one unit to another may occur and are not cause for rejection. Disparities in coloring could be the result of slight variations in the float glass substrate or normal production variations.

Distortion in Insulated Units:

Sealed insulating glass units, regardless of the glass type, exhibit distortion. Air or other gas, sealed in the gap between the lites of glass, expands or contracts with temperature and barometric changes, creating a pressure differential between the sealed gap and the atmosphere. The glass reacts to the pressure differential by being deflected inward or outward.

When inspecting for color uniformity and distortion, glass should be viewed as installed from the exterior at a distance of 10ft (3.0m) at a viewing angle of 90° to the installation with standard day lighting in front of the glass (see figure 3).

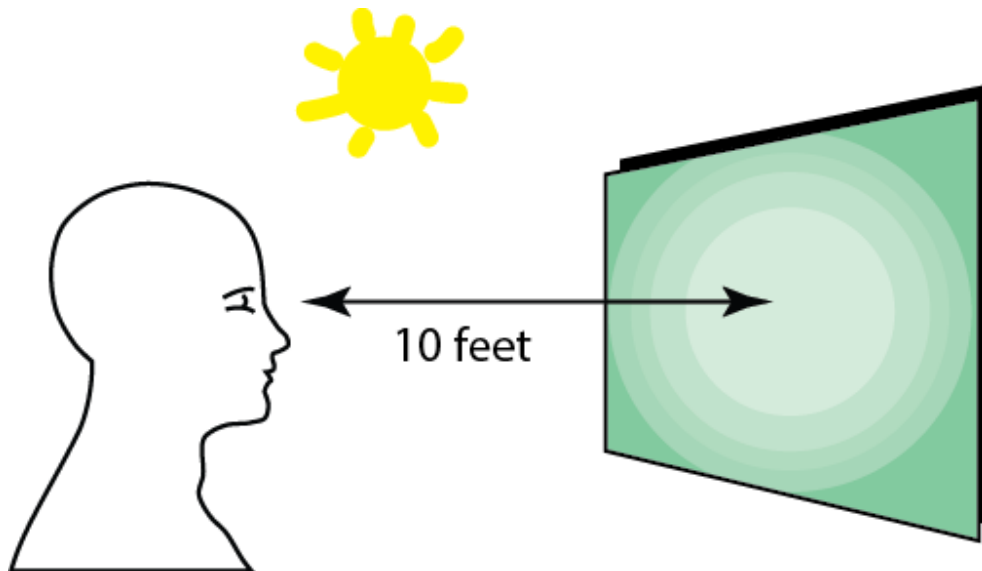


Figure 3: viewing color uniformity and distortion



Laminated Glass

Blemishes in Laminated Glass

All visual inspections shall be made with the naked eye viewing samples in the vertical position at a viewing angle of 90° to the specimen using daylight (without direct sunlight) or other uniform diffused background lighting ([see figure 1](#)) that simulates daylight (minimum 1700 lux measured at the surface of the glass facing the light source). The glass shall be inspected at a distance of 39in (1.0 m). If a blemish is readily apparent under these viewing conditions, refer below to Table 3 to determine acceptability:

Blemish	<25 square feet			≥ 25 square feet		
	Central Area, in.	Outer Area, in.		Central Area, in.	Outer Area, in.	
		Covered Edge	Exposed Edge		Covered Edge	Exposed Edge
Bubbles	1/16	3/32		1/8	3/16	
Blow-in/edge bubble	N/A	1/4	1/16	N/A	1/4	1/16
Hair/Lint	Light*	Medium**		Light*	Medium**	
Inside dirt spot	1/16	3/32		3/32	5/32	
Concentrated lint	Light*	Medium**		Light*	Medium**	
Short interlayer/ unlaminated area chip	N/A	1/4	1/16	N/A	1/4	3/32
Scuff/streak	Light*	Medium**		Medium**	Medium**	

Table 3: maximum allowable laminating process blemishes (verticle glazing)

*Light indicates: barely noticeable at 39in (1m)

**Medium indicates: noticeable at 39in (1m) but not at 10ft (3m)



Bow and Warp in Laminated Glass

Bow/warp measurements shall take place with the glass in a free standing vertical position with the longest edge resting on blocks at the quarter points. With the laminate in this position, place a straightedge across the concave surface, parallel to and within 1 in of the edge and measure the maximum deviation with a taper or feeler gage. A dial indicator may also be used. Below, Table 4 indicates the maximum allowable overall bow and warp for heat-treated laminated glass

Laminate Make-up Two Glass lites of, (in.)	Edge Dimension (in.)											
	0-18	>18-36	>36-48	>48-60	>60-72	>72-84	>84-96	>96-108	>108-120	>120-132	>132-144	>144-156
	Maximum Bow (in.)											
1/8in to 3/16in	1/8	3/16	9/32	3/8	1/2	5/8	3/4	7/8	1	...	...	...
1/4in	1/16	1/8	3/16	9/32	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
5/16in	1/16	3/32	5/32	7/32	9/32	11/32	7/16	9/16	11/16	13/16	15/16	11/16
3/16in	1/16	3/32	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2in	1/16	1/16	3/32	1/8	3/16	1/4	9/32	3/8	1/2	5/8	3/4	7/8

Table 4: maximum allowable overall bow and warp for heat-treated laminated Glass

- Bow and Warp for annealed transparent glass shall not exceed 1/16in per 12in of length

Laminated Glass Mismatch

Mismatch indicates misaligned edges of two lights when laminated. Table 5 indicates length and width tolerances for rectangle shapes of symmetrically laminated glass including mismatch:

Overall Laminate Thickness	Transparent Glass	Patterned and Wired Glass	Heat Strength and Tempered Glass
≤1/4"	+5/32 , -1/16	+5/16 , -1/8	+7/32 , -3/32
1/4" - 1/2"	+1/4 , -1/16	+5/16 , -1/8	+1/4 , -1/8
1/2" - 1"	+1/4 , -1/8	+5/16 , -1/8	+5/16 , -1/8



Table 5: maximum allowable mismatch of laminated glass

Please note that the above mismatch applies to symmetrical laminates without edgework. Add +1/8" and -3/16" to the above length and width tolerances for symmetrical and non-symmetrical laminates requiring fabricated edgework and an additional +/-1/8" to the hole and notch tolerances listed in the fabrication section of this guide. Tighter tolerances may be available on request.

Uniformity and Color Variation in Laminated Glass

The iron content present in standard clear float glass imparts a slight green or blue-green tint that may become more noticeable in glass thicknesses exceeding 3/8"(10mm). This effect may become more pronounced in certain applications, such as bullet resistant glazing, where the laminate contains numerous plies of clear glass. This coloration is not a cause for rejection. In cases that require high levels of optical clarity, low-iron glass should be considered.

The lamination of certain low-E glass products to the interior of the laminate may affect the refractive index of the coating and could potentially cause a slight color shift to that of a non-laminated piece of the same low-E coated glass. Please consult your sales representative should you be installing laminated and non-laminated low-E coated products side-by-side.

Optical Distortion in Laminated Glass

When viewing images through or in reflection from laminated glass, the images may appear distorted. This distortion could arise from internal variations in the interlayer thickness, heat-treatment of the glass, differences in internal and external building pressures, and the manner in which the piece is glazed.

In an effort to increase the resistance to thermally and mechanically applied loads, multiple plies of heat-treated glass are often used in laminated. The inherent distortion characteristics (roller wave, bow, warp, and strain pattern – fully discussed in the following section) of heat-treated glass can accentuate the appearance of distortion and it is recommended that a full-size mock-up be viewed under typical job conditions for evaluation of distortion.



Tempered and Heat Strengthened

Distortion in Heat-Treated Glass

Tristar Glass produces heat strengthened and fully tempered glass by heating annealed glass in a horizontal tempering furnace to a temperature at which the glass becomes slightly plastic. Immediately after heating, the glass surfaces are rapidly cooled by quenching with air. The original flatness of the glass is slightly modified by the process creating some level of surface distortion (picture framing, heat distortion, or roller wave distortion). Distortion may be detected when viewing reflected images from the glass surface.

Regardless of the glass flatness, the degree of reflected distortion perceived is largely due to the characteristics or symmetry of the object being reflected. Linear objects (such as building curtain walls and telephone poles) and moving objects (such as cars) may appear distorted.

Specified Bow limits may not adequately define, or control, the distortion that may become apparent after glazing. The factors noted above, may have a larger influence on the perceived reflected distortion than that which is caused by bow from the heat-treating process. Consultation with suppliers and the viewing of full-size mock-ups, under typical job conditions and surroundings is highly recommended for evaluation of reflective distortion. Table 6 indicates the maximum overall bow allowed in heat-treated glass:



	Edge Dimension (in.)											
	0-20	>20-35	>35-47	>47-59	>59-71	>71-83	>83-94	>94-106	>106-118	>118-130	>130-146	>146-158
Nominal Thickness Designation	Maximum Bow (in.)											
1/8in	0.12	0.16	0.2	0.28	0.35	0.47	0.55	0.67	0.75	...	...	...
5/32in	0.12	0.16	0.2	0.28	0.35	0.47	0.55	0.67	0.75	...	...	...
3/16in	0.12	0.16	0.2	0.28	0.35	0.47	0.55	0.67	0.75	...	...	...
1/4in	0.08	0.12	0.16	0.2	0.28	0.35	0.47	0.55	0.67	0.75	0.83	0.94
3/8in	0.08	0.08	0.08	0.16	0.2	0.24	0.28	0.35	0.47	0.55	0.67	0.75
1/2in	0.04	0.08	0.08	0.08	0.16	0.2	0.2	0.28	0.39	0.47	0.55	0.67

Table 6: maximum allowable overall bow in heat-treated glass.

Strain Pattern in Heat-Treated Glass

A strain pattern, also known as iridescence, is inherent in all heat strengthened and fully tempered glass. This strain pattern may become visible under certain lighting and other conditions. It is a characteristic of heat treated glass and should not be mistaken as 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 and should not be considered a cause for rejection.

Fabrication of Heat-Treated Glass

Heat strengthened and fully tempered glass cannot be cut after the heat-treating process. Fabrication altering the glass surface, thickness, or edges must be performed before heat-treating to avoid reduction of glass strength. Outlined below are fabrication limitations and tolerances.

Placement:

- Distance from glass edge to hole rim shall be 1/4in or 2 x glass thickness (whichever is greater).
- Distance between rims of 2 adjoining holes shall be 3/8in or 2 x glass thickness (whichever is greater)
- Distance of hole to 90° glass corner shall be 6.5 x glass thickness
- Minimum hole diameter = 1/4in or = glass thickness (whichever is greater)
- Notches and Cutouts shall have fillets and radius \geq glass thickness



Tolerance:

Fabrication Attribute	Dimensional Tolerance
Hole Diameter	$\pm 1/16\text{in}$
Hole Center from Edge	$\pm 1/16\text{in}$
Hole Center to Hole Center	$\pm 1/16\text{in}$
Hole Chip and Flake Size	$\pm 1/16\text{in}$
Notches and cutouts	$< 1/2\text{in} = \pm 1/16\text{in}$
	$\geq 1/2\text{in} = \pm 1/8\text{in}$

Table 7: dimensional tolerances for holes and notches in heat-treated glass

Spandrel Glass

All visual inspections shall be made with the naked eye viewing installed specimens from the exterior of the building ([see figure 3](#)) at a distance of 10ft (3.0m) and a viewing angle of 90° to the installation. The glass shall be viewed by light reflected from the viewed surface with an opaque backdrop. Scattered pinholes, screen marks, and small opaque particles in the coating are permissible. Spandrel glass is not to be viewed from the interior or placed in a vision area.

