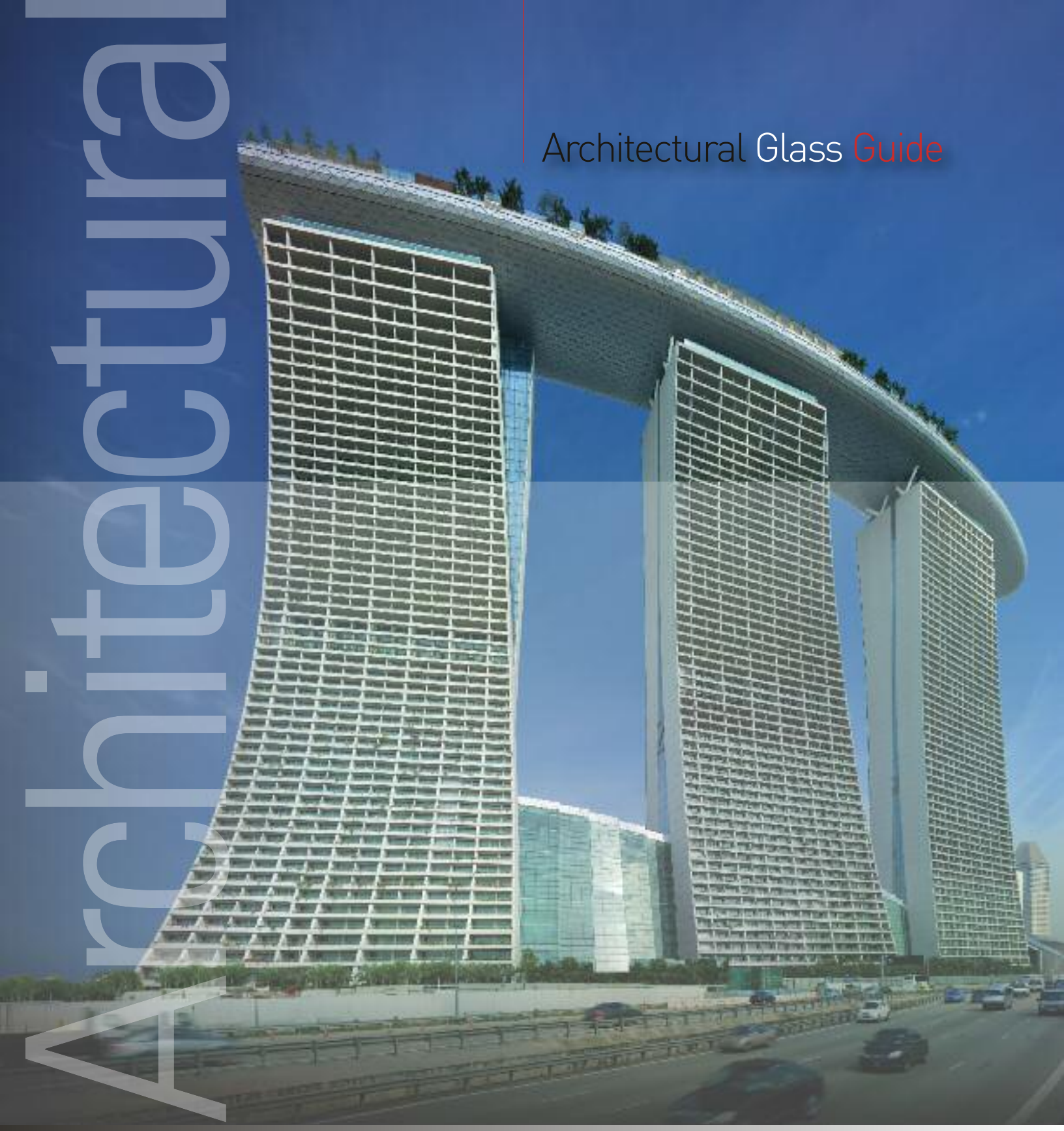
Architectural

Architectural Glass Guide



CARDINAL Glass Industries

ENGINEERING THE FUTURE OF GLASS

Architectural Glass Guide

Cardinal LoĒ Architectural Glass Products Set the Standard

Cardinal Glass Industries is considered one of the world's leading providers of superior quality glass products. From the melting of sand to producing clear float glass to the vacuum sputtering of silver to produce low-emissivity coatings, Cardinal manufactures the quality components and finished insulating glass products used in top-of-the-line buildings around the world.

Cardinal is a management-owned company leading the industry in the development of long lasting, energy-efficient glass products. We have more than 5,500 employees located at 29 manufacturing locations around the United States.

At Cardinal, we try to maintain a clear vision: design and fabricate the most advanced glass products in the industry. To sustain that vision, we invest heavily in research and development. Our twin R&D centers in Minnesota and Wisconsin provide the basis for new advances in glazing fenestration.

Cardinal turns fresh ideas into functional products that our customers can use. We provide a turnkey solution to our customers whether it includes insulating glass, coated, laminated, tempered or just plain float glass. In every case, our solutions always incorporate the latest applied glass science.

Cover Photos and pages 1 & 2:
Marina Bay Project: Singapore
Glass Product: LoĒ³-366
Project size: 35,000 Sq meters
Architect: Moshe Safdie and Associates.

Energy Terminology

U-Value
The heat flow rate through a given construction is expressed in Btu/hr/ft²/°F (W/m²/°C) The lower the U-Value, the less heat is transmitted through the glazing material. Values given for summer daytime are calculated for outside air temperature at 89°F (32°C), outside air velocity at 7.5 mph (12 km/h), inside air temperature of 75°F (24°C) and a solar intensity of 248 Btu/(hr)/(ft²) (790 W/m²). Winter nighttime U-Values are calculated for outside air temperature at 0°F (-18°C), outside air velocity at 15 mph (24km/h), and a solar intensity of 0 Btu/hr/ft² (0 W/m²).

R-Value
Thermal resistance of a glazing system expressed in Hr•ft²•F/Btu. It is the reciprocal of U-Value, R=1/U. The higher the R-Value, the less heat is transmitted through the glazing material. R-Values are not listed.

Shading Coefficient (SC)
The ratio of solar heat gain through a window to the solar heat gain through a single light of 1/8" (3mm) clear glass under the same set of conditions. Dimensionless and varying between 0 and 1, the smaller the number, the better the window is at stopping the entry of solar heat.

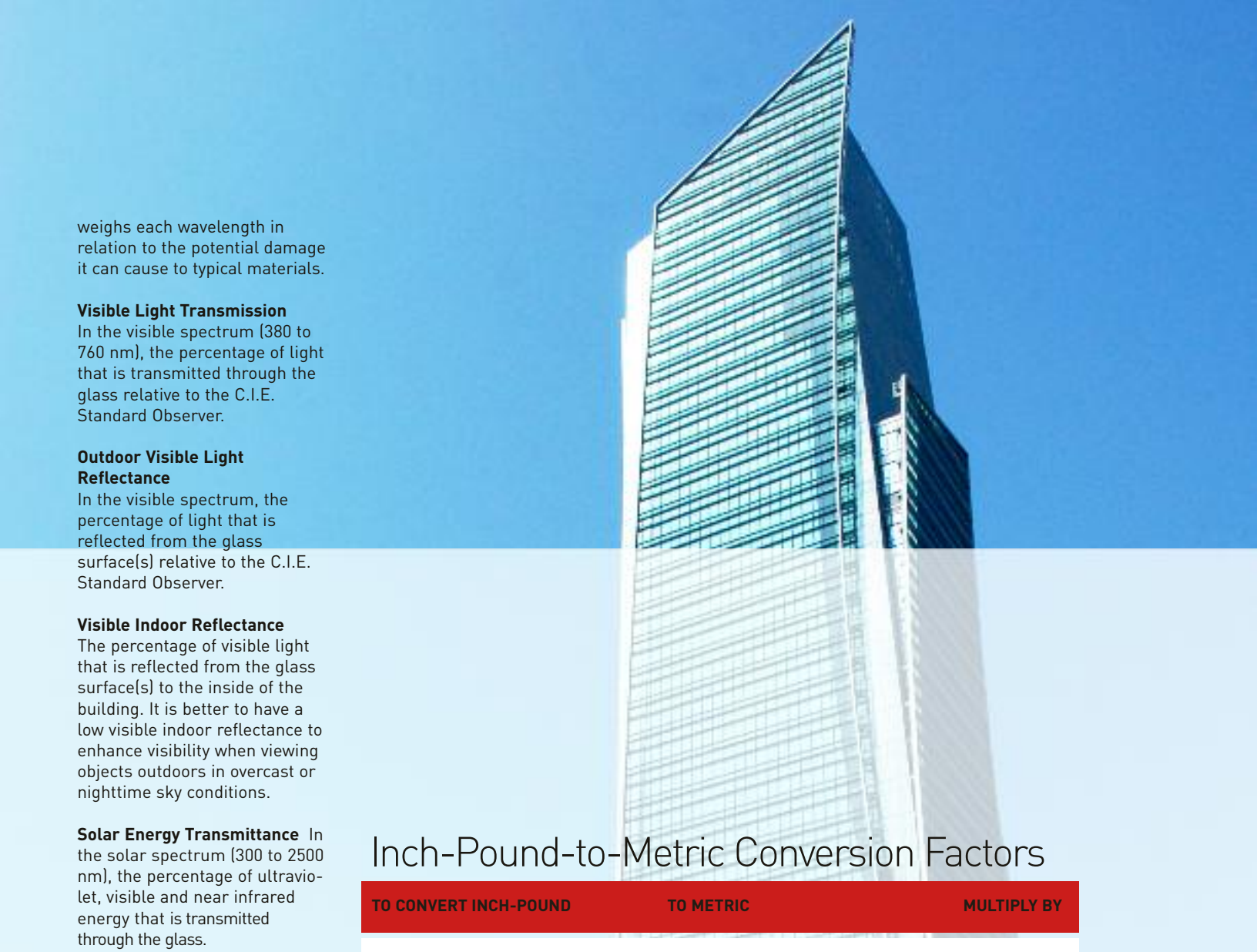
Solar Heat Gain Coefficient (SHGC)
The fraction of incident solar radiation which enters a building as heat. It is based on the sum of the solar energy transmittance plus the inwardly flowing fraction of absorbed solar energy on all lites of the glazing. Dimensionless and varying between 0 and 1, the smaller the number, the better the glazing is at preventing solar gain. It is preferred over the shading coefficient since it can be used for solar incidence angles other than normal to the glass surface.

Relative-Heat Gain (RHG)
The total amount of heat gain through a glazing system at NFRC/ASHRAE specified summer conditions, incorporating the U-Value and the Solar Heat Gain Coefficient. The conditions are 230 Btu/hr/ft² (726 W/m2), outdoor temperature of 89°F (32°C), indoor temperature of 75°F (24°C) and 7.5 mph (12 km/hr) wind. [RHG = U summer x (89-75) + SHGC x (230)]. Expressed in terms of Btu/hr/ft².

Ultraviolet Light
In the solar spectrum (300 to 380 nm), ultraviolet light is considered the energy that accounts for the majority of fading of materials and furnishings.

ISO – CIE Damage Function
In the solar spectrum (300 to 700 nm), the International Standards Organization (ISO) developed a weighting function, recommended by the International Commission on Illumination (CIE) that takes into account not only the UV transmission but also a portion of the visible light spectrum that can cause fading of materials and furnishings.

Krochmann Damage Function
This function attempts to account for the fading potential of all damaging radiation which can be transmitted through glass. It covers a spectral range from about 300 to 600 nm and



weighs each wavelength in relation to the potential damage it can cause to typical materials.

Visible Light Transmission
In the visible spectrum (380 to 760 nm), the percentage of light that is transmitted through the glass relative to the C.I.E. Standard Observer.

Outdoor Visible Light Reflectance
In the visible spectrum, the percentage of light that is reflected from the glass surface(s) relative to the C.I.E. Standard Observer.

Visible Indoor Reflectance
The percentage of visible light that is reflected from the glass surface(s) to the inside of the building. It is better to have a low visible indoor reflectance to enhance visibility when viewing objects outdoors in overcast or nighttime sky conditions.

Solar Energy Transmittance In the solar spectrum (300 to 2500 nm), the percentage of ultraviolet, visible and near infrared energy that is transmitted through the glass.

Solar Energy Reflectance
In the solar spectrum, the percentage of solar energy that is reflected from the glass surface(s).

LSG
Light to solar gain ratio. The ratio of visible light transmittance to solar heat gain coefficient.

Inch-Pound-to-Metric Conversion Factors

TO CONVERT INCH-POUND	TO METRIC	MULTIPLY BY
Inches (in)	Millimeters (mm)	25.4
Feet (ft)	Meters (m)	0.305
Square inches (in^2)	Square millimeters (mm^2)	645
Square feet (ft^2)	Square meters (m^2)	0.093
Pounds (lb)	Kilograms (kg)	0.453
Pounds force (lbf)	Newtons (N)	4.45
Pounds force/in (lbf/in)	Newtons/meter (N/m)	175
Pounds force/inch^2 (lbf/in^2)	Kilopascals (kPa)	6.89
Pounds force/feet^2 (lbf/ft^2)	Kilopascals (kPa)	0.048
Btu/hr	Watts (W)	0.293
Btu/hr/ft^2/°F	W/m^2/°C	5.678
Btu/hr/ft^2	W/m^2	3.15

Project: Al Babtain Cultural Waqf Tower
Location: Kuwait City, Kuwait
Glass Product: LoE²- 270
Architect/ Consultant: Gulf Consults
Glazing Contractor: Yuanda Alum +
Gulf Glass Industries

Cardinal Coated Energy-Efficient Glass Goes Far Beyond Ordinary Low-e Glass

Low Emissivity Coatings

LoĒ Coatings applied to glass which reflect long wave room side infrared energy back into the room reducing the U-Value. Emissivity varies from 0 to 1 and the lower the emissivity, the lower the resultant U-Value.

LoĒ² Second generation of LoĒ coatings which provide a high visible light transmission while offering a significant decrease in solar heat gain coefficient and shading coefficient. These products have two silver layers in the coating stack.

LoĒ³ Third generation of LoĒ coatings which provide the best solar heat gain coefficient and shading coefficient with a high visible light transmission. These products have three silver layers in the coating stack.

HIGH SOLAR GAIN GLASS
[One silver layer]

Cardinal LoĒ-180® is the perfect cold remedy. Ideal for passive solar applications, it allows winter sun's heat to pass into the home while blocking heat loss to the outside.

For years, Cardinal LoĒ glass has been setting the standard for energy-efficient glass. Our patented, state-of-the-art sputtered coatings are unmatched by any other glass manufacturer. Our high transmission coatings are virtually clear, blocking the heat and reducing solar gain, while optimizing light transmission. In fact, our LoĒ^2 and LoĒ^3 coatings actually outperform the tinted glass often used in warm climates. In addition, because our coated glass transmits more natural light and reduces solar gain, you may be able to reduce both lighting and air conditioning electrical loads.

ALL CLIMATE GLASS
[Two silver layers]

Cardinal LoĒ^2-272® glass (pronounced low-e squared 272) delivers year-round performance and comfort, whether it's -20°F (-29°C) or 110°F (43°C) in the shade. In winter, it reflects heat back into the room. In summer, it rejects the sun's heat and damaging UV rays.

ALL CLIMATE SOLAR CONTROL GLASS
[Two silver layers]

Where additional solar control is required, with very little sacrifice in visibility, LoĒ^2-270® is the ideal choice. Its patented coating blocks 86% of the sun's infrared heat and 86% of the sun's harmful UV rays.

ULTIMATE PERFORMANCE GLASS
[Three silver layers]

The new standard, LoĒ^3-366® (low-e cubed 366) delivers the perfect balance of solar control and high visibility - with no room-darkening tints and virtually no exterior reflectance. It provides the highest levels of year-round comfort and energy savings, making it the perfect glass for any location. The secret? An unprecedented three layers of silver.

GLARE CONTROL GLASS
[Two silver layers]

Wherever glare is a problem, LoĒ^2-240® is a smart solution. It's a specially treated version of our LoĒ^2-240 glass that not only controls glare but also blocks oppressive solar heat gain and maintains cool indoor glass temperatures. Regular tinted glass works by absorbing sunlight, so the glass color changes with the thickness and the glass becomes hot in sunlight. However, LoĒ^2-240 maintains its appearance and performance regardless of the glass thickness. It can be used for turtle glass codes.

Architects: SEIS ARQUITECTOS S.A
Project size: 3,500 Sq meters
Glass Product: LoĒ^2 -240
Fabricator : Solaire
Curtain wall company : Solaire
Location: San Salvador, El Salvador

Cardinal LoĒ Glass Delivers Outstanding Thermal Performance

Solar energy can be broken down into the UV, Visible, and Near Infrared spectrums. Characteristics of these energy spectrums are as follows:

- UV, 300 to 380 nm- Can cause fading of furnishings
- Visible, 380 to 760 nm- Visible light
- Near Infrared, 760 to 2500 nm- Solar energy that we feel as heat

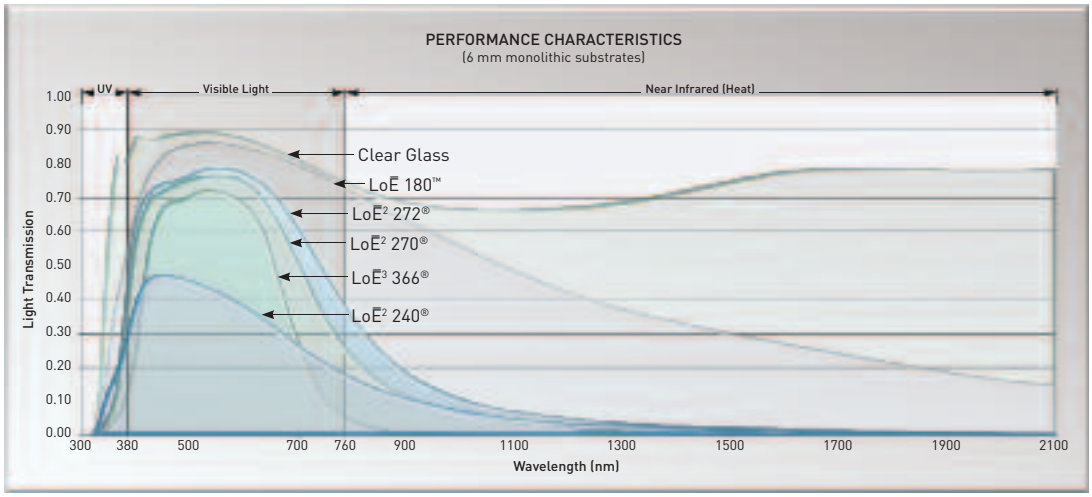
A comparison of the performance of Cardinal's LoĒ products is shown below.

Depending on the application, the best glass product would have a low UV transmission, a high visible light transmission and a low near infrared transmission. Considerations of outdoor aesthetics, color, glare, solar gain (SHGC), heat loss (U-Factor), comfort, visible light transmission, etc., should be taken into account on any application.

All Cardinal LoĒ glass products can be supplied in stock sheets and can be tempered, bent and laminated for stock delivery. Maximum stock sheet size: 96" X 144" (2.43 meters X 3.65 meters)

	Unit Make Up			Visible Light				
	Exterior Lite	Airspace	Inboard Lite	Transmission	Reflectance Exterior	Reflectance Interior	Transmission	Refle Exterior
3mm	*Gray LoĒ³ 366®	13mm	Clear	43%	7%	11%	17%	23%
	*Gray LoĒ² 272®	13mm	Clear	48%	7%	10%	26%	19%
6mm	*Gray LoĒ³ 366®	13mm	Clear	31%	6%	10%	12%	14%
	*Gray LoĒ² 270®	13mm	Clear	34%	6%	11%	16%	13%
	*Gray LoĒ² 272®	13mm	Clear	35%	6%	10%	18%	12%
	Clear	13mm	LoĒ 180®	77%	14%	15%	52%	18%
	LoĒ² 240®	13mm	Clear	37%	13%	10%	19%	27%
	LoĒ² 272®	13mm	Clear	70%	10%	11%	35%	29%
	LoĒ² 270®	13mm	Clear	68%	12%	12%	31%	32%
	LoĒ³ 366®	13mm	Clear	63%	11%	11%	24%	36%
	Arctic Blue	13mm	LoĒ² 270®	40%	7%	10%	17%	8%
	Arctic Blue	13mm	LoĒ³ 366®	37%	7%	9%	14%	8%
	Evergreen	13mm	LoĒ² 270®	50%	9%	11%	19%	7%
	Evergreen	13mm	LoĒ³ 366®	46%	8%	10%	16%	8%
	Blue-Green	13mm	LoĒ² 270®	57%	10%	11%	24%	12%
	Blue-Green	13mm	LoĒ³ 366®	53%	9%	10%	19%	13%
	Bronze	13mm	LoĒ² 270®	40%	7%	11%	19%	17%
	Bronze	13mm	LoĒ³ 366®	37%	7%	10%	14%	9%
	Gray	13mm	LoĒ² 270®	34%	7%	11%	16%	13%
	Gray	13mm	LoĒ³ 366®	31%	6%	10%	12%	15%
	SuperGray	13mm	LoĒ² 270®	6%	4%	9%	3%	4%
	SuperGray	13mm	LoĒ³ 366®	6%	4%	9%	2%	4%
8mm	LoĒ² 240®	13mm	Clear	37%	13%	10%	18%	24%
	LoĒ² 272®	13mm	Clear	68%	10%	11%	33%	24%
	LoĒ² 270®	13mm	Clear	66%	12%	12%	29%	28%
	LoĒ³ 366®	13mm	Clear	61%	10%	11%	23%	31%
	Blue-Green	13mm	LoĒ² 270®	53%	9%	11%	21%	9%
	Blue-Green	13mm	LoĒ³ 366®	49%	9%	10%	17%	10%

1. Data was calculated using the Window 6.3 computer program with NFRC 100-2010 environmental conditions.
2. Gas fill: 90% argon / 10% air.
3. Please contact Cardinal IG for availability of LoĒ Coatings on Tinted Substrates.
4. Heat treatment of the tinted substrate may be required.



Solar Energy						U Factor - Air				U Factor - Argon				Fading		
ctance	SHGC	SC	LSG	RHG		BTU/Hr.ft² °F		W/m² °K		BTU/Hr.ft² °F		W/m² °K		UV Transmission	Krochman Damage Function	ISO CIE
Interior				BTU/Hr.ft²	W/m²	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter			
47%	0.21	0.24	2.05	51	161	0.26	0.29	1.48	1.65	0.21	0.24	1.19	1.36	3%	14%	29%
37%	0.31	0.35	1.55	74	233	0.27	0.30	1.48	1.65	0.22	0.25	1.25	1.42	10%	23%	37%
38%	0.17	0.20	1.82	43	136	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	2%	11%	21%
33%	0.22	0.26	1.55	55	174	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	6%	16%	26%
30%	0.25	0.28	1.40	60	189	0.27	0.29	1.53	1.65	0.22	0.25	1.25	1.42	7%	17%	27%
18%	0.64	0.74	1.21	150	474	0.29	0.30	1.62	1.72	0.24	0.26	1.33	1.47	24%	38%	60%
28%	0.24	0.28	1.54	60	189	0.28	0.30	1.59	1.70	0.23	0.25	1.31	1.42	13%	22%	32%
30%	0.40	0.46	1.75	95	300	0.27	0.29	1.53	1.65	0.22	0.25	1.25	1.42	14%	31%	53%
33%	0.35	0.41	1.94	85	268	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	13%	30%	50%
38%	0.27	0.31	2.33	65	205	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	4%	20%	41%
32%	0.27	0.31	1.48	64	202	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	5%	19%	33%
36%	0.24	0.28	1.54	59	186	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	2%	13%	27%
32%	0.28	0.33	1.79	69	218	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	4%	16%	33%
36%	0.27	0.31	1.70	64	202	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	1%	12%	28%
32%	0.35	0.40	1.63	83	262	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	8%	24%	42%
36%	0.32	0.37	1.66	76	240	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	3%	16%	35%
32%	0.30	0.34	1.33	72	227	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	6%	16%	28%
36%	0.26	0.30	1.42	62	196	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	2%	11%	23%
32%	0.27	0.31	1.26	64	202	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	6%	16%	26%
36%	0.23	0.27	1.35	56	177	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	2%	11%	21%
31%	0.10	0.12	0.60	27	85	0.27	0.29	1.53	1.65	0.21	0.25	1.19	1.42	<1%	3%	5%
36%	0.10	0.11	0.60	25	79	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	<1%	2%	4%
24%	0.24	0.27	1.54	58	183	0.27	0.30	1.53	1.70	0.22	0.25	1.25	1.42	12%	20%	31%
26%	0.39	0.45	1.74	92	290	0.27	0.29	1.53	1.65	0.22	0.25	1.25	1.42	13%	30%	51%
29%	0.35	0.40	1.89	83	262	0.26	0.29	1.48	1.65	0.21	0.25	1.19	1.42	11%	28%	49%
33%	0.27	0.31	2.26	65	205	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	4%	19%	40%
27%	0.32	0.36	1.66	76	240	0.26	0.29	1.48	1.65	0.21	0.25	1.19	1.42	6%	21%	38%
31%	0.29	0.33	1.69	70	221	0.26	0.29	1.48	1.65	0.20	0.24	1.14	1.36	2%	15%	32%

LoĒ Aesthetics

CLEAR GLASS

TRANSMITTED APPEARANCE

EXTERIOR APPEARANCE

CLEAR | LoĒ-180

TRANSMITTED APPEARANCE

EXTERIOR APPEARANCE

Aesthetics of glass products – such as color, transmittance, reflectivity, etc. – are very subjective. Cardinal LoĒ glass is virtually non-reflective, and and its transmitted and exterior appearance covers a range of neutral earth tones. Viewing angle, sky conditions (blue sky vs. overcast), colors of objects being reflected, colors of materials behind the glass (e.g., blinds, draperies) and viewing distance away from the glass will have a dramatic impact on the perceived glass aesthetics. Using clear glass as a basis, the depiction below shows the transmitted appearance and the exterior appearance of Cardinal's LoĒ products.

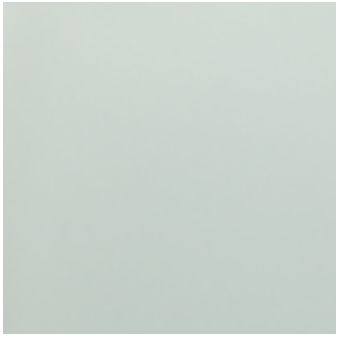
CLEAR | LoĒ²-272

TRANSMITTED APPEARANCE

EXTERIOR APPEARANCE

CLEAR | LoĒ²-270

TRANSMITTED APPEARANCE



EXTERIOR APPEARANCE

CLEAR | LoĒ³-366

TRANSMITTED APPEARANCE

EXTERIOR APPEARANCE

CLEAR | LoĒ²-240

TRANSMITTED APPEARANCE

EXTERIOR APPEARANCE

Architectural

Insulating Glass:
A 70-Year History

Insulating glass was developed and introduced to the commercial marketplace in the late 1930's. Since then, it has been shown that insulating glass (IG) units with LoĒ coatings and argon filling offer significant benefits over single-glazed windows:

- Reduced window U-factor saves energy in wintertime
- Reduced solar heat gain coefficient (SHGC) saves on summertime air conditioning costs
- Improved acoustical properties mean better sound attenuation
- Reduced UV transmission reduces the potential for fading of furnishings
- Increased roomside temperature of the IG unit in winter climates improves comfort and reduces the potential for condensation on the indoor pane of glass
- Reduced roomside glass temperature in summertime conditions improves comfort

Essentials of manufacturing long-lasting IG units

What makes a long-lasting IG unit?
- Material selection of unit components
- Workmanship of unit fabrication
- How the units are glazed

Material selection
The sealant(s) used to bond glass to the spacer system is the most important material used in IG unit construction. The sealant(s) must resist temperature extremes, UV radiation, moisture ingress into the airspace and retain any inert gas in the airspace, i.e. argon. Cardinal has chosen a dual-seal system with polyisobutylene (PIB) as the primary seal and silicone as the secondary seal.

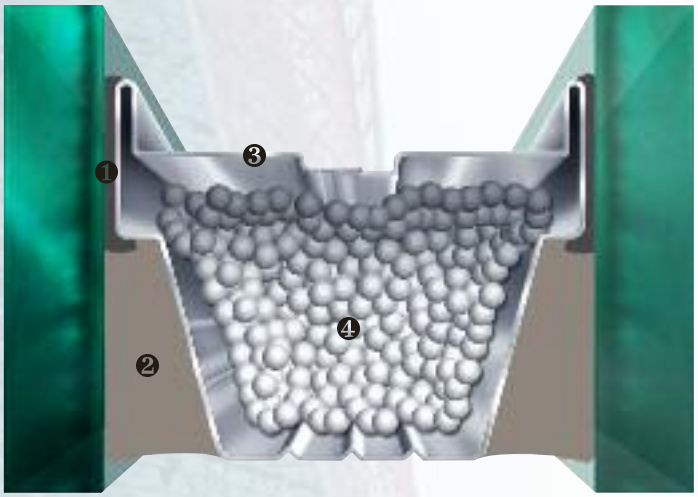
In addition to sealant choice, spacer design and processing are also important. Cardinal uses four bent corners in our construction which requires only one joint on the spacer. Many other IG manufacturers use corner keys to attach the four spacer pieces together. Four joints instead of one significantly increases the potential for moisture ingress into the IG unit airspace.

Workmanship
Critical to IG unit longevity is fabrication consistency. There must be no voids allowed in the seal system. Cardinal's unique Intelligent Quality Assurance Program virtually eliminates anomalies in the fabrication process. All inspections rely on carefully calibrated scientific instrumentation, so results are objective. In addition, Cardinal manufactures its own production equipment to ensure that units are fabricated with consistent high quality.

How the units are glazed
If an IG unit sits in water or the seal system is overstressed, there is no unit construction that will deliver long-term performance. Cardinal believes that our dual-seal construction is the most versatile IG seal system because of its excellent weatherability. In fact, in both real-world and simulated weathering conditions, Cardinal's dual-seal system outperforms other IG unit constructions.

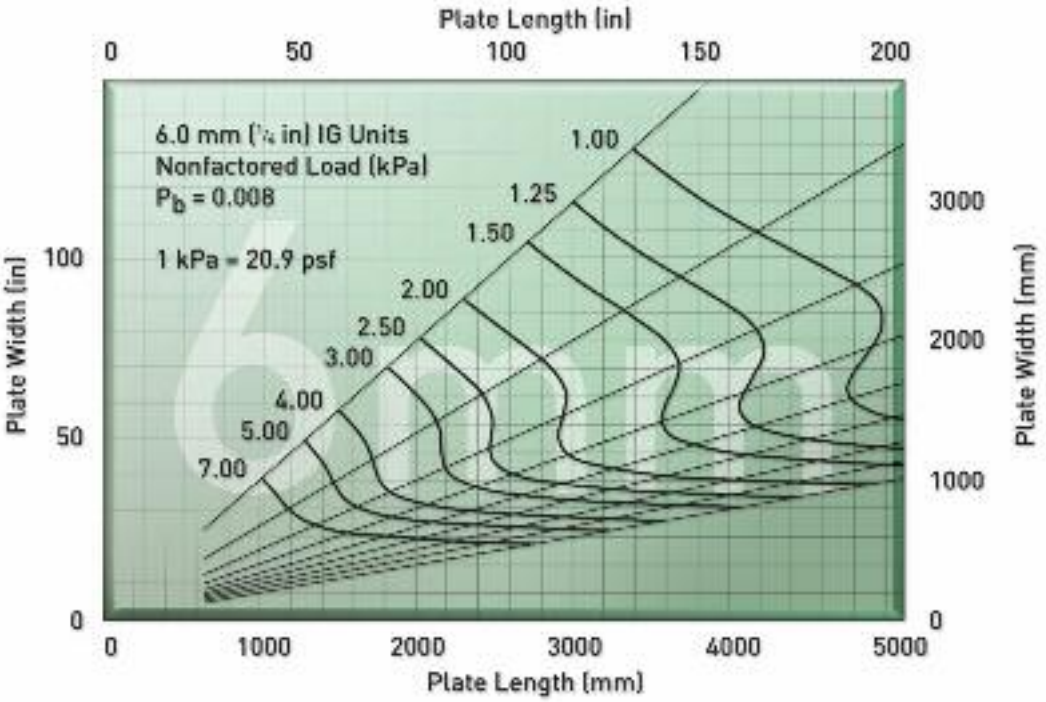
Cardinal IG Unit Cross Section

1. PIB primary seal. Stops moisture from entering the airspace and has the lowest moisture vapor transmission and argon permeation of all known sealants used in the manufacturing of IG units.
2. Silicone secondary seal. Recognized as the best sealant for resisting weathering and adhering to glass substrates.
3. Stainless steel spacer (0.006in or 0.008in). Increased resistance to condensation and least stress on IG seal system.
4. Desiccant. Removes moisture from airspace and designed for a 125-year life.

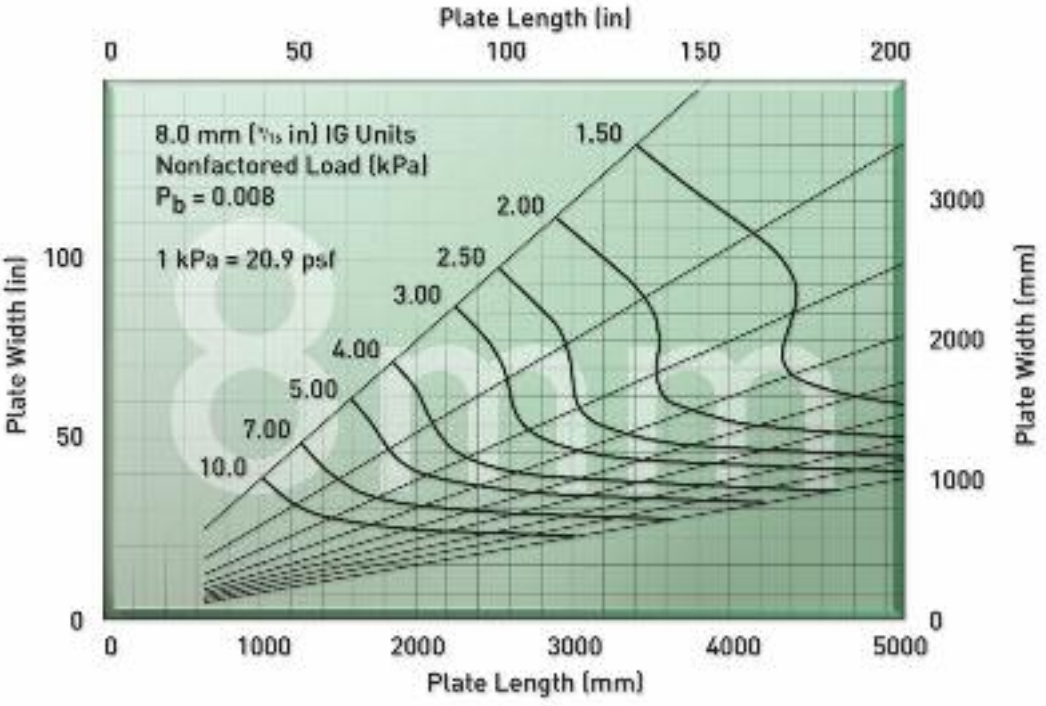


Project: Capital Gate Tower - ADNEC
Location: Abu Dhabi
Glass Product: LoE²-240
Project size: 29,000 Sq meters
Architect: RMJM
Glazing contractor: White Aluminum

6mm IG Wind Load Chart



8mm IG Wind Load Chart



Wind Loads and Insulating Glass Size Limits

The wind load data presented is based on ASTM Standard E 1300-04 (Standard Practice for Determining Load Resistance of Glass in Buildings) for annealed glass.

The charts may be used by the design professional to choose the appropriate glass product to meet the wind load criteria specified. The charts are for insulating glass units and assume four-sided support with support deflections not greater than L/175 of the span at design load, and a uniform 3-second load duration.

Breakage probability for insulating glass is 8/1000 units. By definition, breakage of either lite in an insulating glass unit constitutes unit breakage. The 8/1000 unit breakage probability is the combined probability for both lites when the unit is exposed to design load.

How to use the wind load chart and design factors:

- Locate the long dimension and short dimension on the chart.
- Draw a vertical line from the long dimension and a horizontal line from the short dimension.
- At the point where these lines intersect, interpolate between the wind load (kPa) contours to determine the allowable wind load. For windload in PDF, use the conversion factor in chart.
- If the glass construction other than annealed-annealed is to be used, determine the wind load for the annealed-annealed glass with the appropriate glass thickness, and multiply this wind load by the appropriate load factor (see Load Factors at right).

Load Factors

Annealed-Annealed	1.0
Heat Strengthened-Annealed	1.11
Heat Strengthened-Heat Strengthened	2.0
Heat Strengthened-Tempered	2.11
Tempered-Tempered	4.0

Note: Load factors assume the following:

1. Heat strengthened glass to have a surface compression between 24.1 MPa (3,500 psi) and 51.7 MPa (7,500 psi).
2. Tempered glass to have a surface compression of 69 MPa (10,000 psi) minimum.
3. Duration of load is 3 seconds.
4. 8/1000 probability of failure.

Project: Rotana Hotel @ Yas Island
Location Abu Dhabi
Glass Product: LoE²-240
Project Size: 7,000 Sq meters
Aluminum Contractor: Alico
Architect Consultant: ML Design

Glazing Guidelines

The following guidelines are presented to assist the design professional in the recommended handling and use of glass products offered in this brochure.

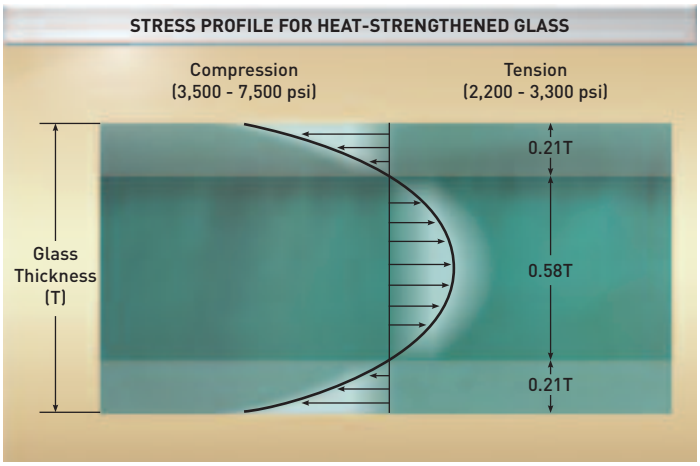
Guidelines are offered on the requirements of framing systems to minimize the potential of glass breakage and possible seal failures of insulating glass units. Additional glazing recommendations may be found in the GANA (Glass Association of North America) Glazing Manual (Current Edition). Failure to adhere to the minimum recommendations listed and those presented in the GANA Glazing Manual may invalidate Cardinal's product warranties.

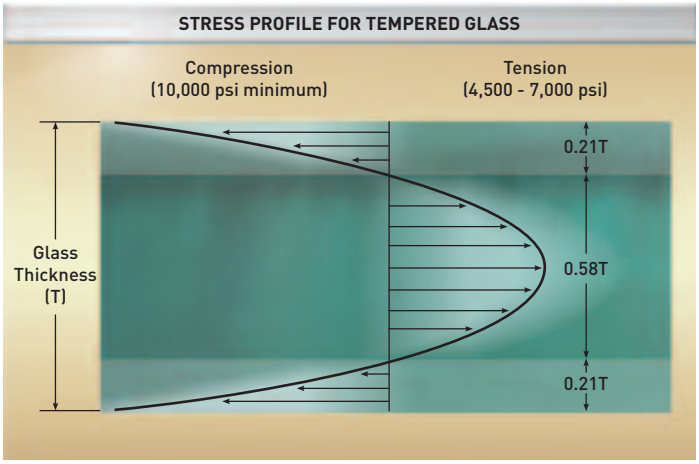
GLASS TYPES

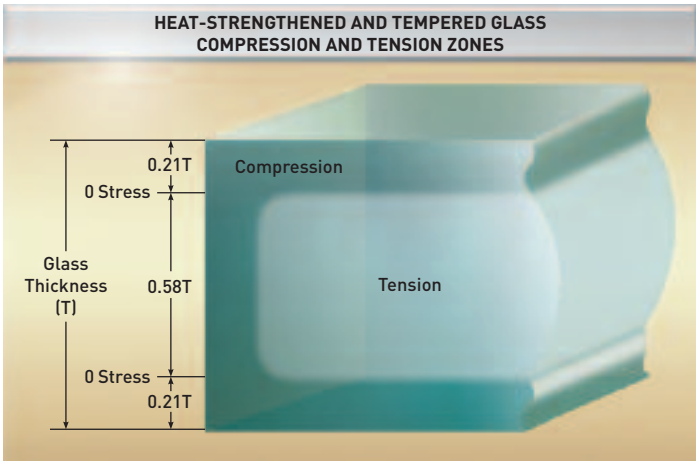
Annealed Glass:
Annealed glass can be used for vision applications where clear, tinted and LoĒ glasses are specified, provided they meet the windload, thermal stress and building code requirements of the project.

Heat Strengthened Glass:
Heat strengthened glass is approximately two times as strong as annealed glass in resisting windload. If it fractures, it usually breaks into large sections (similar to annealed glass) and usually remains in the opening. If it meets all requirements, codes and specifications, heat strengthened glass should be used in all applications where annealed glass will not meet thermal or windload requirements. Heat strengthened glass can be used for all tinted, LoĒ and reflective vision applications. It is the recommended choice for all spandrel applications.

Tempered Glass:
Tempered glass is approximately four times as strong as annealed glass in resisting wind load. If fracture occurs, it will break into very small particles which usually will evacuate the opening and could cause damage or injury to people below. Because of this, Cardinal recommends that the use of tempered glass in commercial construction be restricted to applications where codes require safety glazing, fire knockout panels







or in non-hazardous applications where glass fallout potential is not a concern.

HEAT STRENGTHENED/ TEMPERED GLASS MANUFACTURING

Glass tempering and heat strengthening are processes of heating annealed glass to approximately 1200°F (650°C) and then rapidly cooling it with air. The resultant piece of glass is thermally strengthened resulting in it being approximately two to four times stronger than a piece of annealed glass. This increased strength is the result of permanently locking the outer surface molecules of the glass in compression and the center portion in compensating tension.

Bow/Warp:

Since the glass is reheated to its softening point and then rapidly cooled, a certain amount of warp or bow is normally associated with each piece of heat treated glass. Generally this warp or bow is not a significant factor to the design professional. On occasion it shows up as distorted reflected images under certain viewing conditions and will be more noticeable as the outdoor reflectance of the glass increases.

Strain/Pattern:

A visible phenomenon of tempered and heat strengthened glass is a strain pattern that might appear under certain lighting conditions, especially if it is viewed through polarized lenses. The strain pattern can appear as faint spots, blotches or lines; this is the result of the air quenching (cooling) of the glass when it was heat treated and is not a glass defect.

Distortion:

Distortion can occur in all glass products (i.e. annealed, heat treated, monolithic, insulating, coated or non-coated). These sometimes visible phenomena are the direct result of light being reflected and refracted at different angles and speeds through uneven glass surfaces which occurred during the air quenching process.

Mirror-like images should not be expected from glass that has been tempered or heat strengthened. Quality standards for various sizes and thicknesses of heat treated glasses are detailed in ASTM Specification C1048-04. Some glass products will tend to accentuate distortion levels if they have a relatively high outdoor reflectance. Viewing angle, glass type, sky condition, time of day, glass orientation and the type and amount of reflected images all affect the perceived degrees of distortion in any glass product. Causes of distortion can be attributable to one or a combination of the following factors:

1. Roll Ripple
   a. Heat treatment process for heat strengthened and tempered glass
2. Bow or Warp (either positive or negative)
   a. Heat treatment process
   b. Differences between insulating glass airspace pressure and barometric pressures
   c. Difference between insulating glass airspace temperature and outdoor temperature
   d. Static or dynamic pressure differences from indoors to outdoors (i.e. windload, buildings internal pressure, etc.)
   e. Glazing stop pressure
   f. Framing manufacturing and erection tolerance
   g. Insulating glass airspace fabrication pressures

It is Cardinal's intent to control and minimize distortion levels in processes under our control. The glazing system, temperatures and pressures greatly influence the amount of distortion. It is recommended that the design professional responsible for glass selection view a mock-up of the intended glass choice in an environment as close as possible to the actual building site to determine if the glass product meets the aesthetic objectives of the project.

Face Clearance, Edge Clearance and Bite:

The glazing system should provide recommended face and edge clearances and bite to retain the glass in place under windload. It also should thermally and mechanically isolate the glass from the framing members to prevent glass to metal contact. Sealants or gaskets should provide a watershed with an approximate height of 1/16" (1.6mm) above the edge or sightline of the glass framing members. The bite plus watershed should be large enough to cover the insulating glass sightline.

Setting Blocks:

Glass lights should be set on two 80 to 90 durometer neoprene setting blocks positioned at the quarter points. When this is not practical, the setting blocks can be installed to within 6" (152mm) of the vertical glass edge. Length of the setting block should be 0.1" (2.5mm) in length for each square foot of glass area, but no less than 4" (102mm) in length. The setting block should be 1/16" (1.6mm) less than the full channel width and be of sufficient height to provide the nominal recommended bite and minimum glass edge clearance.

Weep Systems:

Water should not be permitted to remain in the glazing rabbet. A weep system should incorporate enough weep holes to ensure adequate drainage; usually this consists of three 3/8" (9.5mm) diameter holes or equivalent, equally spaced at the sill.

Framing Recommendations:

The framing system should provide structural support for the glass and under design loads must not exceed either the length of the span divided by 175 or 3/4" (19mm) whichever is less. Horizontal member deflection due to the glass weight should be limited to 1/8" (3mm) or 25% of the design edge clearance of the glass or panel below, whichever is less. In dry-glazed gasket systems, compressive pressure exerted at the glass edge should be 4 to 10 pounds per lineal inch (700 to 1750 N/n).

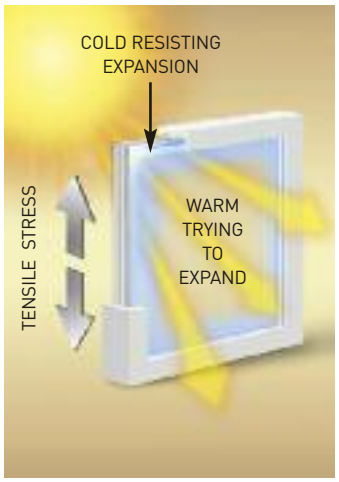
Insulating Glass Framing Recommendations

Overall Thickness	Face Clearance	Edge Clearance	Bite
1" (25mm)	3/16" (4.8mm)	1/4" (6mm)	9/16 (14mm)

Glazing Guidelines (continued)

THERMAL STRESS AND GLASS BREAKAGE

When window glass is warmer at the center relative to the edge as shown below, the expansion of the central zone places a tensile stress on the glass edge. Based upon the coefficient of thermal expansion for soda lime glass, a 1° F (.55°C) temperature gradient creates 50 psi (345 kPa) mechanical stress in the glass edge. When the stress exceeds the strength of the glass edge, a thermal fracture can occur. Low stress fractures, i.e. less than 1,500 psi (10,335 kPa) stress, can be characterized by a single fracture line perpendicular to the glass edge. Typically a flaw or chip can be found at the edge (origin) of this type of fracture. Higher stress fractures can be characterized as having multiple vent lines running into the daylight opening.



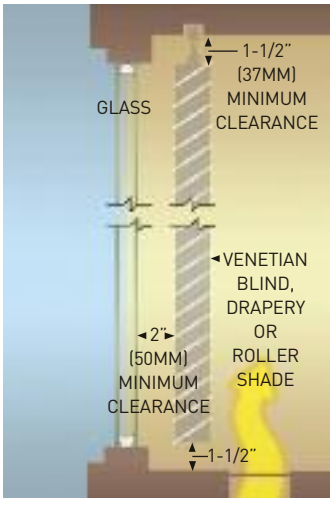
Basically there are three worst case conditions in which to evaluate the stresses in glass and the impact on breakage expectations. The conditions are: cold winter night, cold winter day with high solar load, hot summer day with high solar load. Each of these conditions creates the following responses in a sealed, double glazing unit.

1. Cold Winter Night

Under these conditions the interior lite of glass will be exposed to the maximum thermal stress. The thermal resistance of the IG unit keeps the central glass region relatively warm. At the edge of glass, however, the thermal conductivity of the IG edge seal and the frame design will drop this glass edge temperature significantly. This warm center/cold edge condition now creates tensile stresses and increased breakage potential.

2. Cold Winter Day with High Solar Load

Solar absorptance in the interior lite of glass will increase its central temperature and the resulting thermal stresses. In addition, any shading devices used on the inside of the window will tend to trap and/or reflect heat back at the glass, further increasing the glass temperatures. In either case, the effect of solar loads on the edge temperatures are minimal. This may lead to higher stress potentials than the winter night-time conditions if the solar absorptance of the interior lite is greater than that of clear glass.



3. Hot Summer Day with High Solar Load

Clear glass with its low solar absorptance is not affected by these conditions. Absorbing glasses (i.e. LoĒ coated and/or tinted) can see a greater heat build up under these conditions. If the glass edge is shaded due to a window or building projection, the non-uniform heating of the glass surface then can lead to thermal stresses.

Features that can affect thermal stress on glass are as follows:

- Glass type (thickness, tint, coating type)
- Condition of glass edges
- Shadow patterns on glass
- Heat trap caused by closed blinds or draperies
- Amount of solar radiation
- Outdoor-Indoor temperatures
- Framing material
- Glass size

Outdoor Shading:

Static and moving shade patterns on glass from building overhangs, columns, trees and shrubbery and other buildings create varying degrees of thermal edge stress on the glass. The glass type (clear, tinted, LoĒ), glass size and thickness, degree and type of shadow pattern, outdoor temperature extremes and time of the year all influence the amount of thermal edge stress. If thermally induced stress is high enough, glass fracture could occur. In most applications, thermal stresses caused by the above are not high enough to cause breakage of heat treated glasses but could cause breakage of annealed glass. Cardinal offers a glazing review on projects to recommend specific glass types and treatment to reduce the potential of thermal breakage.

Indoor Shading:

Draperies, venetian blinds or other interior shading devices must be hung so as to provide space at the top and bottom or one side and bottom 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:

1. Minimum 1.5" (38mm) clearance required at the top and bottom or one side and bottom between shading device and surrounding construction, or a closure stop of 60° from horizontal for horizontal blinds.
2. Minimum 2" (51mm) clearance between glass and shading device.
3. Heating/cooling outlets must be to room side of shading device.

Heat strengthening or tempering of the glass may be necessary to offset the effects of a lack of adequate ventilation.

The following are recommendations for blinds and draperies to reduce glass thermal stress:

1. Vertical blinds are recommended over horizontal blinds.
2. Dark blinds are recommended over light blinds.
3. Open weave draperies are recommended over continuous material.
4. A closure stop is recommended on horizontal or vertical blinds to prevent them from closing completely.
5. A natural air vent is recommended across the head of the horizontal detail.

Glazing Review:

Cardinal offers a glazing review with windload and thermal stress analysis on projects that will use our glass. To provide a complete and thorough review, Cardinal requests the following information:

1. PROJECT NAME
2. LOCATION
3. DESIGN WINDLOAD OR WIND STUDY RESULTS
4. TAKE-OFF (listing sizes, quantities, and glass types)

5. PRINTS, SHOP DRAWINGS, or other detailed information which will reveal the following:
   a. Type and Color of Frame (conventional aluminum, rubber ziplock, structurally glazed, other)
   b. Typical and Extreme Canopy Measurements with Respective Elevations (left and right projections, overhang)
   c. Location of any Set-Back or Inside Corners (list true elevation)
   d. Glazing Details
      Setting blocks (type and qty/unit).
      Edge blocks (type and qty/unit).
      Edge clearance
      Bite weep system
      Gasket types;
      Wet seal (types and usage)
      Wall type (strip window, curtain wall, punched opening)
6. AREAS ADJACENT TO BUILDING WITH HIGH REFLECTANCE (concrete, water, light colored sill or adjacent walls)
7. TYPE OF INTERIOR SHADING (color, vented or not, drapes or blinds, open or closed weave)
8. WINTER-TIME GLAZING OR NOT
9. ARCHITECTURAL SPECIFICATIONS

Customer Responsibility: It is the responsibility of Cardinal's Customer to make certain that the above minimum and GANA glazing guidelines are followed. Other requirements, i.e. material submittals and testing, etc. may be required depending on the scope of the project.

Glass Breakage:
An extremely high percentage of glass breakage in monolithic and insulating glass units can be attributed to:
1. Glass damage to the surface and edge caused by poor handling procedures and/or metal to glass contact in the sash.
2. Windblown debris and falling objects.
3. Thermal stress caused by a temperature difference from the center of the glass to the edge of the glass. To reduce the potential of glass breakage from thermal stress, keep outdoor shadow lines to a minimum and follow the indoor shading and heat duct locations listed.

Causes of Insulating Glass Failure: Insulating glass seal failures can usually be attributed to:
1. Incompatibility of glazing materials with the insulating glass sealants
2. Water in glazing rabbet
3. Non-support of both glass lights with setting blocks

Sloped Glazing:
Any glass installed more than 15° off the vertical plane is considered to be sloped glazing. Ultimately, the safest practical glass combinations which we recommend are tempered on the "top side" and laminated heat strengthened on the "bottom side."

However, the design professional must consider many requirements for each particular project and choose the proper glass combinations. Generally, the following items should be considered in product selections:
- Safety for the occupants, should glass fall out after breakage
- Live and dead loads (wind, snow, rain)
- Solar exposure
- Proper drainage
- Proper security
- Mechanical system requirements
- Fire codes or other applicable glazing codes
- Design esthetics glazing angle
- Snow and ice build up which could create a safety issue when it falls

U-Values and heat gains for sloped glazing applications are dependent upon glazing angle, compass orientation and indoor thermal conditions.

Cardinal will recommend glass thicknesses for sloped glazing applications, provided the following variables are supplied:
1. Architect's Design Windload (psf)
2. Architect's Design Snowload (psf)
3. Glazing Angle
4. Glass Size
5. Glass Construction

Coating Quality Specifications for Cardinal Reflective Glass:
The following specifications are applicable to Cardinal LoĒ Glasses when viewed against a bright uniform background.

Vision Glass:
Coating Uniformity: A slight variation in color, reflectance, and transmission is acceptable when viewed from a distance of 10 feet (3m).

Guide Specification

The following guide specification is recommended for specifying Cardinal LoĒ insulating glass products:
A. Cardinal IG LoĒ Products
B. Dual Sealed Insulating Glass: Butyl primary, Silicone secondary seal, Bent corners, Air filled or Argon filled
C. Certified through the Insulating Glass Certification Council (IGCC) or the Insulating Glass Manufacturers Alliance (IGMA) in accordance with ASTM Specification E-2190
D. Winter nighttime U-Value (see performance data).
E. Shading Coefficient, Solar Heat Gain Coefficient

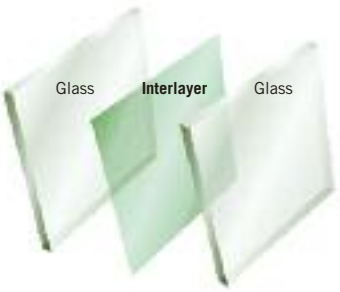
(see performance data and glass type).

Physical Properties of Cardinal IG Units

Glass Exterior (mm)	Glass Interior (mm)	Approximate Weight Lbs/ft²	Overall Thickness Tolerance	Maximum Dimension	Maximum Area Annealed Glass	Dimension Tolerance
6.0	6.0	6.5	+1/32" (+ .8mm) -1/16" (-1.6mm)	144" (3,658mm)	50 sq. ft. (4.6 sq.m)	+1/16-1/8" (1.6mm-3.2mm)
8.0	8.0	8.3	+1/32" (+ .8mm) -1/16" (-1.6mm)	144" (3,658mm)	50 sq. ft. (4.6 sq.m)	+1/16-1/8" (1.6mm-3.2mm)

Note: Thicknesses are based on ASTM C-1036 Std.

Laminated Glass



Cardinal laminated glass consists of annealed, heat-strengthened or tempered glass with one or more transparent interlayers sandwiched together to create a stronger, sturdier glass unit. We offer multiple interlayer options to meet various codes and security constraints.

ANNEALED GLASS breaks easily, producing long, sharp splinters.

TEMPERED GLASS shatters completely under higher levels of impact energy, and few pieces remain in the frame.

LAMINATED GLASS may crack under pressure, but tends to remain integral, adhering to the plastic vinyl interlayer.

Safety Glazing

Cardinal certifies their laminated glass products through the Safety Glazing Certification Council (SGCC) sampling and testing program. The SGCC is an independent agency which confirms that laminate products meet the following requirements:

- ANSI Z97.1-2009 Class "A" (0.030" interlayer and thicker)
- ANSI Z97.1-2009 Class "B" (0.015" interlayer)
- CPSC 16CFR 1201 Cat II (0.030" interlayer and thicker)
- CPSC 16CFR 1201 Cat I (0.015" interlayer)

Blast Resistance

Cardinal laminated glass can qualify for the Department of Defense Unified Facilities Criteria for blast resistance.

Performance Specifications

Cardinal laminated glass provides design flexibility to meet industry requirements. The performance tables below show characteristics of SGP and PVB Laminates. This represents a sample of possible laminate configurations and merely reflects some of the major elements in glass selection.

SGP (SENTRYGLASPLUS)

Name	Laminate Make-up	Visible Light Transmittance	Visible Light Reflectance Out	Visible Light Reflectance In	Solar Heat Gain Coefficient (SC = SHGC/0.87)	U-factor (Btu/hr/ft²/°F) (W/m²)	UV Transmission	Fading (T_{dw}) Krochmann Damage Function	Fading (T_{dw}) ISO CIE
8.6M	3.1 / 0.090" SGP / 3.1	86%	8%	8%	0.76	**0.97** (5.51)	<1%	29%	60%
8.6BM	3.1 Bronze / 0.090" SGP / 3.1	62%	6%	6%	0.66	**0.97** (5.51)	<1%	21%	43%
8.6GM	3.1 Gray / 0.090" SGP / 3.1	59%	6%	6%	0.64	**0.97** (5.51)	<1%	21%	42%
8.6NM	3.1 Green / 0.090" SGP / 3.1	80%	7%	7%	0.64	**0.97** (5.51)	<1%	27%	55%
8.6MX	3.1 LoE³-366 / 0.090" SGP / 3.1	61%	13%	13%	0.34	**0.97** (5.51)	<1%	16%	38%
8.6NMX	3.1 Green / 0.090" SGP / 3.1 LoE³-366	56%	10%	11%	0.41	**0.97** (5.51)	<1%	14%	34%
8.6GMX	3.1 Gray / 0.090" SGP / 3.1 LoE³-366	42%	8%	11%	0.37	**0.97** (5.51)	<1%	11%	26%
8.6BMX	3.1 Bronze / 0.090" SGP / 3.1 LoE³-366	47%	8%	12%	0.37	**0.97** (5.51)	<1%	11%	28%
10.1M	3.9 / 0.090" SGP / 3.9	88%	9%	9%	0.77	**0.96** (5.46)	<1%	31%	62%
10.1MX	3.9 LoE³-366 / 0.090" SGP / 3.9	61%	12%	12%	0.34	**0.96** (5.46)	<1%	16%	38%
10.1GMX	3.9 Gray / 0.090" SGP / 3.9 LoE³-366	39%	7%	10%	0.37	**0.96** (5.46)	<1%	10%	24%
10.1BMX	3.9 Bronze / 0.090" SGP / 3.9 LoE³-366	43%	8%	11%	0.37	**0.96** (5.46)	<1%	11%	25%
11.7M	4.7 / 0.090" SGP / 4.7	86%	9%	9%	0.73	**0.95** (5.42)	<1%	30%	60%
11.7NMX	4.7 Green / 0.090" SGP / 4.7	75%	7%	7%	0.59	**0.95** (5.42)	<1%	25%	51%
11.7GMX	4.7 Gray / 0.090" SGP / 4.7	50%	5%	5%	0.57	**0.95** (5.42)	<1%	18%	36%
11.7BMX	4.7 Bronze / 0.090" SGP / 4.7	56%	6%	6%	0.59	**0.95** (5.42)	<1%	18%	37%
11.7MX	4.7 LoE³-366 / 0.090" SGP / 4.7	60%	11%	12%	0.35	**0.95** (5.42)	<1%	16%	37%
11.7NMX	4.7 Green / 0.090" SGP / 4.7 LoE³-366	55%	10%	11%	0.43	**0.95** (5.42)	<1%	13%	32%
11.7GMX	4.7 Gray / 0.090" SGP / 4.7 LoE³-366	35%	7%	10%	0.37	**0.95** (5.42)	<1%	10%	22%
11.7BMX	4.7 Bronze / 0.090" SGP / 4.7 LoE³-366	40%	7%	10%	0.38	**0.95** (5.42)	<1%	10%	23%
13.6M	5.7 / 0.090" SGP / 5.7	84%	7%	7%	0.71	**0.94** (5.36)	<1%	29%	59%
13.6GM	5.7 Gray / 0.090" SGP / 5.7	43%	5%	5%	0.54	**0.94** (5.36)	<1%	16%	31%
13.6BM	5.7 Bronze / 0.090" SGP / 5.7	52%	5%	5%	0.58	**0.94** (5.36)	<1%	16%	34%
13.6NM	5.7 Green / 0.090" SGP / 5.7	72%	6%	6%	0.55	**0.94** (5.36)	<1%	24%	49%
13.6MX	5.7 LoE³-366 / 0.090" SGP / 5.7	58%	14%	13%	0.35	**0.94** (5.36)	<1%	16%	36%
13.6NMX	5.7 Green / 0.090" SGP / 5.7 LoE³-366	52%	10%	11%	0.42	**0.94** (5.36)	<1%	14%	33%
13.6GMX	5.7 Gray / 0.090" SGP / 5.7 LoE³-366	31%	7%	10%	0.37	**0.94** (5.36)	<1%	9%	21%
13.6BMX	5.7 Bronze / 0.090" SGP / 5.7 LoE³-366	38%	7%	10%	0.38	**0.94** (5.36)	<1%	9%	22%

PVB (POLYVINYL BUTYRAL)

Name	Laminate Make-up	Visible Light Transmittance	Visible Light Reflectance Out	Visible Light Reflectance In	Solar Heat Gain Coefficient (SC = SHGC/0.87)	U-factor (Btu/hr/ft²/°F) (W/m²)	UV Transmission	Fading (T_{dw}) Krochmann Damage Function	Fading (T_{dw}) ISO CIE
6.0L	2.7 / 0.030" PVB / 2.7	89%	9%	9%	0.80	**1.01** (5.74)	<1%	27%	59%
6.0GL	2.7 / 0.030" PVB Gray / 2.7	44%	6%	6%	0.63	**1.01** (5.74)	<1%	17%	33%
11.7L	4.7 / 0.090" PVB / 4.7	87%	9%	9%	0.73	**0.94** (5.34)	<1%	24%	56%
11.7BL	4.7 / 0.090" PVB Bronze / 4.7	49%	5%	5%	0.60	**0.94** (5.34)	<1%	13%	30%
11.7GL	4.7 Gray / 0.090" PVB / 4.7	51%	5%	5%	0.58	**0.94** (5.34)	<1%	16%	34%
13.6L	5.7 / 0.090" PVB / 5.7	86%	9%	9%	0.71	**0.93** (5.28)	<1%	22%	54%
13.6GL	5.7 / 0.090" PVB Gray / 5.7	44%	5%	5%	0.59	**0.93** (5.28)	<1%	17%	33%
13.6GL	5.7 Gray / 0.090" PVB / 5.7	45%	5%	5%	0.54	**0.93** (5.28)	<1%	14%	30%
13.6BL	5.7 Bronze / 0.090" PVB / 5.7	52%	6%	6%	0.56	**0.93** (5.28)	<1%	14%	32%
13.6BL	5.7 / 0.090" PVB Bronze / 5.7	48%	5%	5%	0.58	**0.93** (5.28)	<1%	13%	29%
13.6NL	5.7 / 0.090" PVB Green / 5.7	72%	7%	7%	0.67	**0.93** (5.28)	<1%	22%	49%

Notes:

1] PVB green is the same as PVB blue-green

2] Name Code: G = Gray glass, B = Bronze glass, N = Green glass, L = PVB interlayer, M = SGP interlayer, X = LoE³™ 366 coating

Architectural

Count on Cardinal Glass to Always Meet or Exceed Your Specifications

Cardinal I.Q. – our Intelligent Quality Assurance Program – ensures the quality of every piece of glass. Using our own patented inspection systems, we thoroughly examine the glass from start to finish.


Argon-Fill Levels


Strain Measurement


Exterior Color
Room Side Color and Visible Transmission/Reflection


Coating Color

FLOAT GLASS I.Q.
Float glass is the foundation of all Cardinal products.

Annealing
By providing a uniform glass temperature, this cooling process helps create the inherent strength of the glass and maximizes the ability to cut the finished product.

Strain Measurements
Three different strain measurements are taken, so we can precisely control the strain on the ribbon which also affects the cuttability of the glass.

Thickness Profile
By gauging the thickness across the entire ribbon, we can determine if any portion is out of specification.

Defect Detection
Our laser system inspects 100% of the glass, detecting defects as well as ribbon edges, knurl mark and distortion.

Optimization System
This process arbitrates the best cut for the ribbon, which helps maximize production and efficiency in order to keep costs down.

Emissions Conformance
Cardinal is committed to the environment, and all facilities are equipped with the latest technologies to reduce emissions.

COATED GLASS I.Q.
Cardinal employs patented, state-of-the-art sputter coating processes that are unmatched by any other glass manufacturer.

Exterior Color
Exterior color is validated in process as well as off-line. This specific technology provides analysis based on how the complete product will appear in its final installation. Production measurements enable us to statistically control the existing process and use the data as benchmarks for continuous improvement efforts.

Room Side Color and Visible Transmission/Reflection
Cardinal-specific technology provides continuous load-to-load monitoring to validate film stack construction.

IR Reflection
This measurement validates and ensures coating performance by measuring infrared reflection.

Edge Deletion
Statistically managing this process ensures that customers will not incur edge delete issues such as sealing an unprepared surface.

Performance Testing
R&D conducted evaluations look at every potential variable that can arise along the way. Customized for production, in-process testing is continuous and recorded into our electronic Quality Management System.

TEMPERED GLASS I.Q.
Cardinal tempering increases the glass strength to nearly four times that of ordinary glass, while distortion remains minimal and color is virtually unnoticeable.

Hawkeye Camera
This high-resolution, high-speed camera is used to detect scratches, coating faults and debris on the surface.

Tempered Distortion
Competitive inspection systems read the peaks and valleys that develop as part of the tempering process but they report only an average. And not all lites are measured. Our state-of-the-art camera system measures the entire glass, focusing on a series of circles (similar to pixels). The results represent what the human eye sees.

Defect Detection
Our system accurately characterizes defects by size and sorts them according to our specifications. This prevents defective glass from proceeding to high-value operations.

INSULATING GLASS I.Q.
Cardinal IG units deliver outstanding thermal performance and extremely low failure rates.

Vision Scope and Hawkeye Cameras
This is where scratches, coating faults and debris on the glass surface are detected. The systems accurately characterize defects by size and sort them according to specifications preventing defective glass from proceeding to high-value operations.

Edge Thickness
Our Press Master ensures the precise thickness of each IG unit to within thousandths of an inch.

Argon-Fill Levels
Our unique on-line system measures the argon fill levels of our IG unit and verifies initial fill rates. Cardinal's IG units meet European standards of argon loss not to exceed 1% per annum.

Coating Color
A Minolta spectrophotometer checks color intensity and hue. To avoid rejection of the unit, each different coating must meet specific color values.

Center of Glass Thickness
Where possible, we do a 100% sort inspection of all important attributes, including unit or center of glass thickness. If the unit fails, it is not sealed.


IR Reflection


Defect Detection


Vision Scope and Hawkeye Cameras


Hawkeye Camera


Tempered Distortion

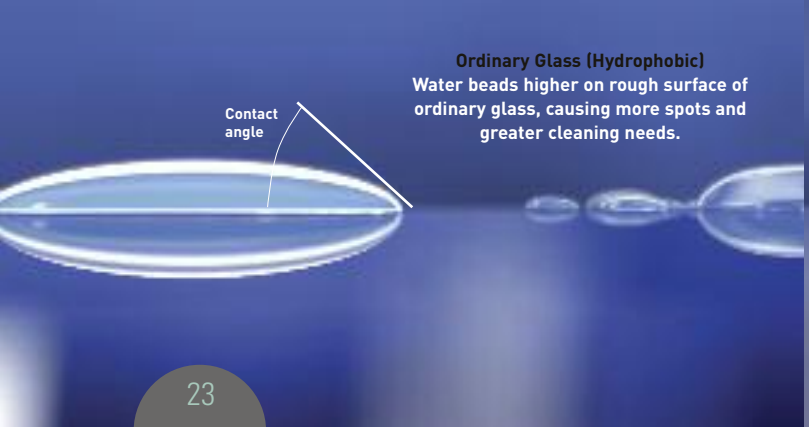
Naturally Clean Glass

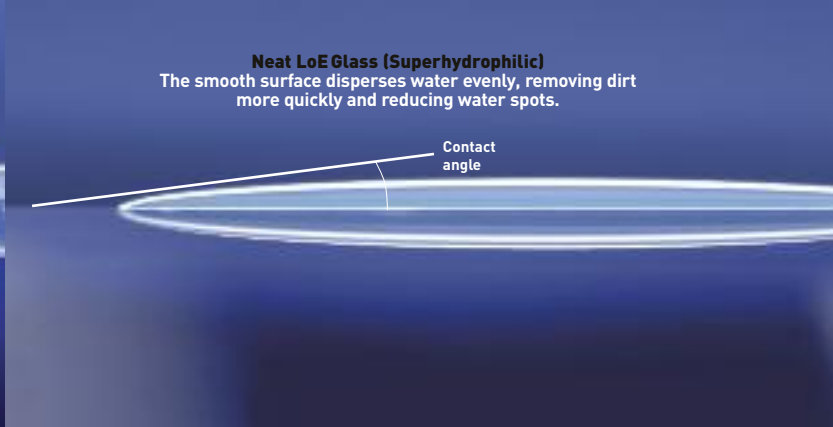
Windows clean easier and stay cleaner.
Neat® coated glass harnesses the power of the sun's UV rays to loosen dirt so water can rinse it away, leaving windows virtually spotless. Windows clean easier and stay cleaner. Because Neat coated glass is available with any of our LoĒ coatings, you get all of the LoĒ coating performance benefits as well.

The science of Neat coated glass.
A variety of different technologies go into manufacturing Neat glass. But the key technology—the one that helps windows stay clean longer—is the super-thin coating we apply. Using our patented double-sputtering process, we apply an invisible, durable and permanent coating of silicon dioxide and titanium dioxide.The cleaning process starts with ultra-smooth glass. Silicone dioxide makes Neat glass smoother as glass ages. In fact, it's much smoother than ordinary glass. So water disperses evenly, sheets off and evaporates quickly, greatly reducing water spotting.

The sun and rain finish the job.
Titanium dioxide reacts chemically with the sun's UV rays, causing organic materials that are on the glass to decompose. It works even on cloudy days. When it rains, the decomposed dirt is rinsed away, leaving the glass almost spotless. Builders and homeowners spend less time washing windows.

Clear advantages over competitive products.
Neat coated glass allows more visible light transmittance than any comparable competitive product and is also less reflective.





Protective Film

At Cardinal our goal is to ensure that glass leaves our factories in perfect condition. However, after it leaves the production facility, glass can be damaged in shipping and handling. Glass can get scratched or damaged on the job site during construction. It can also get spattered with materials used in the construction process, i.e., paint, stains, stucco, spackling, etc. Glass is also exposed to the dirty environment in construction that will leave mud, dust and dirt on the glass.

With Preserve® film, cleanup is a snap. Preserve film is a clear protective film that is factory-applied in overlapping layers, ensuring that the entire glass surface is protected. It can be applied to both the inner and outer surfaces of IG units.

After the job's completed, Preserve film easily peels off, taking all the accumulated dirt and labels with it. There's no need for razor blade cleanup so you reduce the risk of scratched glass and the costly window replacement associated with it.

Because Preserve film contains no harmful chemicals or by-products, it can be disposed of with the rest of normal construction site debris. Preserve film saves you time, money...and a lot of hassle.

Facts about Preserve® film

- Preserve film incorporates a water-based adhesive and is rated as a low density polyethylene. 4 LDPE
- Preserve film should be removed within one year of installation.
- Preserve film contains no harmful chemicals or by-products and can be disposed of with normal construction site debris.
- Preserve film should not be pressure washed.
- Do not affix permanent grilles or external fixtures directly to Preserve film.
- Acid should not be used on Preserve film.
- Do not use razor blades or metal scrapers to remove Preserve film.
- Preserve film is covered by one or more of the following U.S. patents: 5,020,288; 5,107,643; 5,599,422; and 5,866,260.

Indoor



Outdoor



Architectural

Company Structure

Cardinal Glass Industries is a corporation with five wholly-owned subsidiaries. Cardinal enjoys a broad base of domestic and foreign customers.

Cardinal IG Company
(Insulating Glass)
Fargo ND (T)
Fremont, IN (T)
Greenfield, IA (T)
Hood River, OR (T)
Roanoke, VA (T)
Spring Green, WI (T)
Tomah, WI (T)
Waxahachie, TX (T)
Wilkes –Barre, PA (T)

Cardinal CG Company
(Coated Glass)
Buford, GA (T)
Northfield, MN, (T)
Spring Green WI (T)
Waxahachie, TX (T)
Galt, CA (T)
Tumwater, WA (T)
Loveland, CO (Tempered only)
Casa Grande, AZ (Temp. only)
Moreno Valley, CA (Temp. only)

Cardinal LG Company
(Laminated Glass)
Amery, WI
Ocala, FL (T)

Cardinal ST Company
(Solar Technologies)
Spring Green WI
Mazomanie, WI (T)

Cardinal Glass Industries
Eden Prairie, MN, USA

Cardinal IG R&D
St Louis Park, MN, USA

Cardinal CG R&D
Spring Green, WI, USA

Certification Programs

Certification programs like these help us make sure that our product designs comply with government safety and durability.

Insulating Glass Certification Council (IGCC)
Insulating Glass Manufacturers Alliance (IGMA)
National Fenestration Rating Council (NFRC)
Safety Glazing Certification Council (SGCC)
Conformity to CEN (European Committee for Standardization) Program Requirements

Standards and Codes

By complying with established standards, our inherent quality and product performance are fully recognized.

ASHRAE
ASTM International
Canadian General Standards Board (CGSB)
International Code Council

Trade Associations

Cardinal supports industry efforts in research, education and the advancement of building science through work with these organizations.

American Architectural Manufacturers Association (AAMA)
Center for Glass Research
Insulating Glass Manufacturers Alliance (IGMA)
Society of Vacuum Coaters
Window & Door Manufacturers Association (WDMA

Cardinal FG Company
(Float Glass)
Mooresville, NC
Durant, OK (T)
Winlock, WA
Chehalis, WA (TG)
Menomonie, WI
Portage, WI
Tomah, WI (TG)

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