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Newsletter from the Sealed Insulating Glass Manufacturers Association

SG-2000-92

Making a Difference in Glass Deflection/Image Distortion

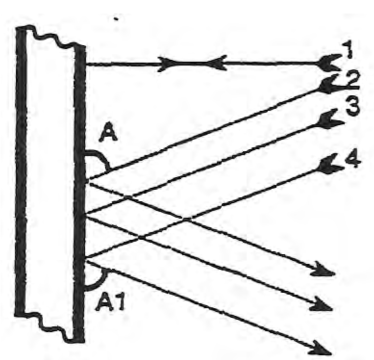
The unique benefits of today's glass products – high energy savings, beauty, durability and visual transparency – are making a difference in the types and styles of insulating glass (IG) units used in the exterior walls of today's residential and commercial buildings.

These benefits have prompted many state energy enforcement agencies to ensure that standards now utilize window areas of thermal insulation values that are only attainable with insulating glass units of thermally controlling coated glasses. By 1995, the glass area energy standards for all states will require minimum energy values for residential and commercial buildings that can only be achieved through the use of high performance insulating glass units.

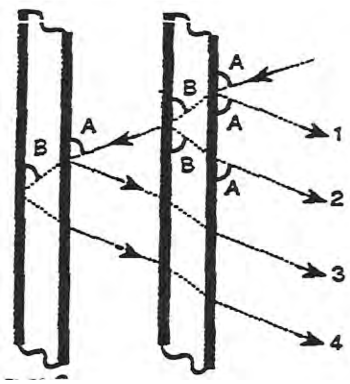
While much has been written about the improved energy performance properties of IG units, there is little published on the distinct optical phenomenon that is inherent in all insulating glass units: Reflective Image Distortion. All industries involved in construction have experienced image reflectance when using glass. Most owners and architects have learned to consider the "non-linearity of reflective images" as a positive design feature. This article will present background information to explain the causes of Reflective Image Distortion.

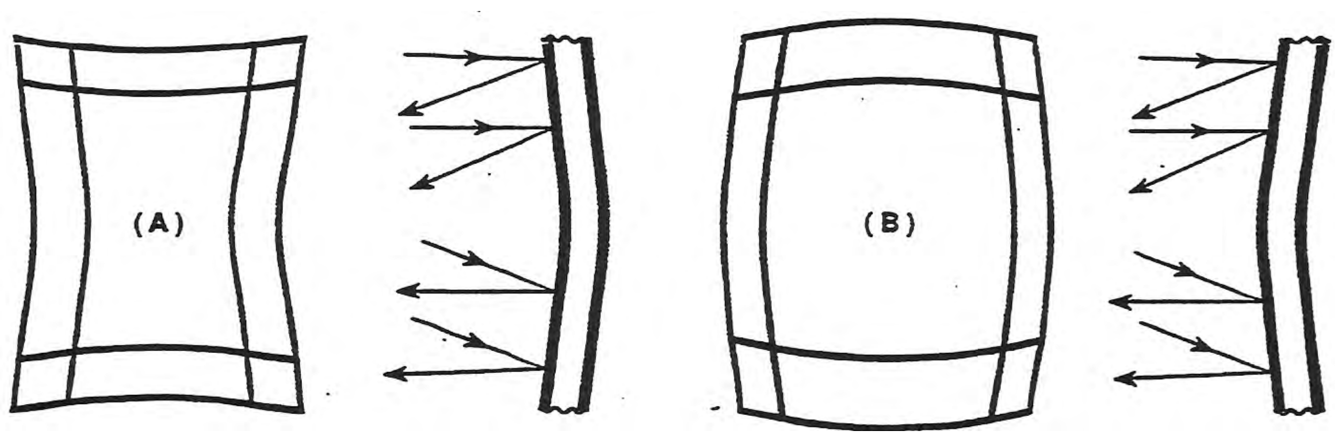
Light Beams

Light is transmitted through space as wave fronts, traveling in all directions from the sun. By the time light reaches the earth, some 9.3 millions miles away, the light waves are essentially straight lines and parallel to each other. When light falls onto a smooth glass surface, some rays are transmitted through, some are reflected back and some are absorbed. If the incident rays are directly perpendicular to the glass surface, they are reflected straight back as sown in Figure 1. If the incident rays (2, 3, and 4) fall obliquely upon the glass surface, their reflective rays bounce back at the same angle but to the other side of the normal perpendicular. The angle of incidence (A) always equals the angle of reflection (A1).



As the transmitted light rays enter the glass, as shown in Figure 2, they are abruptly bent (refracted) at an angle (B) of lesser degree than the incident angle. As the refracted rays reflect from the second glass surface, it is again refracted as it leaves the first glass surface at an angle equal to the original incidence angle. For each light of glass there are two reflected images; a primary image and a secondary image. With a dual pane insulating glass unit, there are two primary, spaced images (surfaces #1 and #3) and two secondary, spaced images (surfaces #2 and #4). The spacing of these four images from each other will increase and become more noticeable as the incident angle decreases, the glass thickness increases and the air space increases. (These four images can be seen by holding a lighted match near an IG unit and viewing from an angle.)





When light rays strike a curved glass surface, they reflect in different directions obeying the law of the angle of incidence equals the angle of reflection. All objects being reflected from curved glass surfaces are distorted from their actual form. If the glass curvature is concave, the reflected light rays are projected inward toward a central point causing the reflective image to appear to be short and thin (see Figure 3-A). If the glass curvature is convex, the reflected rays are projected outward causing the reflective image to be stretched out in both directions (B). In insulating glass units experiencing load changes due to elevation, air temperature or barometer, both glass lights will be in reversed curvature, altering significantly the shape of the object being reflected.

Light, in its transmission, refraction and reflection behaviours, is rather east to understand when the glass is flat. The reflective images seen are multiples but exactly like the object reflected. However, when we deal with sealed insulating glass units, both the glasses are in constant bending movement resulting in multi-directional scattering of the image reflection and pronounced distortion. Such is an indefinable optical behaviour that is inherent in IG units. The causes of distortion are the physical behaviour of IG units under weather and installation conditions. While these conditions are simple to understand, they are impossible to control. It is amazing to recognize glass's ability to adjust through glass deflection to these extremely high load forces.

We will now consider the influences of environmental conditions on glass deflection. Loads will be given, at times, in wind load equivalent pressures to more easily appreciate the magnitude of the daily forces placed on the IG unit's glasses and edge seal.

Causes of Glass Deflection in Insulating Glass Units

An insulating glass unit is a flexible pressure chamber. It contains the pressure of the elevation, barometer and air temperature that was in the manufacturing plant at the moment the unit was sealed. Since these weather conditions change daily – or even hourly – no two units have the identical built-in air pressure. The glasses in a sealed insulating glass unit will deflect if the pressure in the unit's air space is different than that of the surrounding environment. The degree of glass deflection depends upon the difference in these two pressures, the size of the IG unit, its glass and air space thicknesses and its aspect ration. All of these influences are considered by SIGMA manufacturers in the design of their insulating glass units. The unit's edge seal receives the major attention in design because if its singular important job of producing long term unit field performance. It is recognized that the most positive and attainable action to control high sealant stressing is to permit the deflection of the glass lights.

The various pressures that an IG unit must sustain are generally extremely high and interacting: sometimes additive and sometimes counter-balancing. Let's first consider the forces presented by the environmental conditions of elevation changes, temperature changes and barometric changes.

Elevation

When an IG unit is installed at an elevation above that which it was made, the lower elevation pressure causes the two glasses to bow outward. As the elevation differences increases, the relatively higher air space pressure becomes more dominant producing greater deflection.

An IG unit made in St. Louis (505 feet elevation) and glazed in Cincinnati (1063 feel elevation) will take a convex shape when experiencing this minus pressure change of 36 PSF (or that produced by a leeward 118 MPH wind). Conversely, and IG unit made in Atlanta and glazed in Philadelphia will have concave bowed glasses due to the drop in elevation of 1,000 feet, or the equivalent of an 168 MPH wind. Seventy percent of our states have elevation differences within a state of over 500 feet. Sixteen states have elevation differences of over 1000 feet.

The influence of elevation change on IG unit glass bowling is also influenced by the building floor on which the unit is glazed. With an IG unit made in the same city in which it is glazed, the second floor units will have negative outdoor elevation pressure equal to a 16 MPH wind, on the firth floor equal to 37 MPH windows and on the tenth floor equal to 53 MPH winds. Deflection distortion increases as the height of the building increases.

Temperature Changes

An IG unit's air space temperature, and thereby its internal pressure, is directly influenced by the ambient air temperature and the solar radiation striking the glass. As the air space temperature heats up, the internal pressure increases. As the air space temperature goes down, the internal unit pressure goes down. These changes vary by hour, day, and season of the year and by geographical location. The heat absorbing property of specific glasses and glass coatings also alter the unit's air space temperature.

Every one degree Fahrenheit (F) change in the air space temperature from that at which the unit was built produces a 3.6 MSF pressure change. While this seems slight, a 20 degree F change would equal the pressure of a 175 MPH wind. In the southern states where the winter temperatures reach 30F, the air space temperature would be 50F or 20 degrees from the 70F manufacturing temperature. In the northern states where the outdoor temperature reaches 0F, the internal pressure would be negative 130 PSF (equals 230 MPH winds, if the glasses did not deflect.

A photograph of the same IG unit in the winter, spring, summer and fall would record differences in image distortion. The same IG unit on the same day but receiving direct solar radiation will also show significant differences in appearances. Even a cloud passing in front of the sun causes a measurable deflection change in glass flatness.

Barometric Pressure

The continuing change in the outdoor barometric pressure from the pressure contained in the unit's air space is another cause of glass deflection. A recent check on Philadelphia's barometric pressure showed a change of 0.39 inches of mercury between two consecutive days. This is a pressure change of 28 PSF or the equivalent of the force of a 105 MPH wind storm. In the United States, it is fairly common to experience a cycle of high to lower pressure systems over a period of three to four days giving pressure variations of 50 PSF. With a decrease in barometric pressure, the IG unit's glass lights will bow outward.

Over most of our country, the barometric pressure is lower in the summer and higher in the winter. With this happening, we have the summer higher air space temperature causing the glasses to bow outward and also the lower barometric pressure adding to the outward deflection of the glass lights.

Wind Loads and Air Conditioning Loads

Other influences of glass deflections are the forces produced by wind loads and the indoor operating forces of the air conditioning and heating operations.

Wind forces- from mild to storming conditions – load the glass area of the building with positive forces on the windward side and suction forces on the other three leeward building sides. When there are climatic conditions also bearing on the building causing an outward deflection of the glasses (high elevation, high temperature, lower barometer), the deflection of the glasses facing the storm are counteracted by these positive wind loads. At the same time the outward bowed glass of the other three elevations are further deflected outward.

The two to three PSF inner building loads resulting from the operation of the air conditioning and heating equipment also add to the incidence of glass deflection and distortion. With these loads resisting the inward deflection of the IG unit's indoor glass light, the unit's internal pressure transfers the second light inward deflection into additional outdoor glass deflection.

Tempered Glass and Glazing Distortions

Besides the IG unit glass deflections produced by the ever changing environmental loads, image distortions are also caused by the heat treatment of glass and by glass bending that occurs in glazing installations.

Glass is heat treated to produce a strength level – or a break pattern – as required by a building specification. All heat strengthened and tempered glasses processed through roller hearth furnaces contain repeating lines of glass thickness variations (waves) that extend across the glass width dimension as it passes through the oven. The ceramic rollers that transfer the glass through the furnace produce very slight indentations into the glass surface at the temperature required for successful heat treatment. The radius of curvature of these waves is very small but does produce discernible reflective image distortion.

To minimize the noticeable effect of roller waves, these glasses should be glazed with the roller waves horizontal to the glass's sill edge. An observer traveling alongside the building will not see the repeating pattern of image distortion. If, however, the observer is traveling toward the building, he will see this inherent distortion-producing blemish.

Glazing frames have their inherent manufacturing tolerances and are sometimes installed without precise plumbness with adjacent glazing frames. The change in the viewer's angle of incidence of light rays will cause a striking difference in the appearance of any reflected object. For image uniformity, the adjacent glasses must be in the exact same planes. Even a slight bow in a glazing frame or a corner area being out of plane will cause the glass to bend and show reflective distortion. Corner area distortion is caused by joint assembly misalignment, the less compressibility of glazing gaskets at their welded corners and the testing blocks frictional resistance to glass final outward movement during compression glazing.

Lessening The Degree of Glass Distortion

A sealed insulating glass unit will always display reflective object distortion because weather, wind and glazing will produce ever changing pressure loads that differ from the pressure locked in during the manufacturing. There is no way to eliminate reflective distortion in insulating glass units and only a few IG unit construction modifications to produce noticeable changes.

Venting of the IG unit's air space is a common practice to provide adjustment for major elevation pressure changes. This is achieved by one or two methods. Breather holes – or breather tubes – installed during unit manufacturing into the IG unit's spacer are generally about 1/8" in inside diameter and will rapidly adjust the inside unit pressure as higher elevations are reached. The breather hole of units must be permanently sealed after a relatively short time on the building site to preserve the low moisture content of the air space. The IG unit manufacturer will advise the elevation above which breather units should be ordered. Very precise instructions are given for field sealing these breather holes which must be exactly followed to preserve the warranty on the IG unit's field performance.

Capillary tube units, which are a more recent development, contain a factory installed 12" long metal tube that has a 0.021" inside diameter. Because of the length of these tubes and their very small inside diameter, they are reported to prevent the influx of moist air to the extent that the desiccant would be affected. The capillary tubes remain open upon glazing and give a constant balancing of internal and external pressures. Unit size, air space thickness and pressure differential are all influences to the response time to achieve full pressure equalization.

Rectangular IG units of large aspect rations and with thicker glasses do reduce glass deflection, but remember that all such steps will not change the pressure differentials created by the changing environment. If glass deflection is so restrained, the remaining very considerable pressure will act on the long term durability of the IG unit's edge seal.

The use of glasses of different thicknesses in an IG unit (with the thinner, more deflecting glass inboard) is a unit construction method used to decrease outdoor viewed distortion. In such cases, a full study of the glass strength capacity of the thinner glass light must be made.

On triple and quadruple glazed units, the interior glass lights should contain a hole to provide for air space equalization. If this is not done, the exterior air space and outdoor glass light will experience very excessive pressures.

Reflective distortion in IG units is not a recently developed phenomenon but one that has been in existence since insulating glass units have been marketed. Clear glass units are deflecting exactly the some today as they did 30 years ago. Distortion has become more noticeable because of its visibility brought on by colored and coated glasses. With the high light transmission and low reflectance of clear glass, image reflectance is subdued when there is reasonably high indoor illumination. As the IG units act more like mirrors (low indoor illumination or tinted and coated glass), image reflectance becomes very pronounced.

If reflective distortion is a considerable problem, remember you need only be concerned with the likely location of the observer, the height of the reflecting building and the height of your building. Generally only the first, second or third floor of a building will ever be critically reviewed

Every morning, look at your building and enjoy the reflective distorted images. If such are not occurring, the IG unit has lost its seal. Remember, glass deflection prevents IG unit seal failure.

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SG-1992

PUMPING NEW LIFE INTO OLD BUILDINGS

Industry focuses on Renovation: Quality Windows Play Key Role

No significant recovery is anticipated in the building construction industry until 1993 or 1994, reports an article in the January 13, 1992, issue of Business Week. With the current national average vacancy rate of 19% in office buildings and 40% in hotels, the article concludes that there is no need for commercial construction in 1992.

Some growth in the residential building market will occur due to the recent lowering of interest rates on mortgages, but with the average home priced at $ 102,000, only a modest increase is expected. Residential apartment buildings have only a 9% vacancy rate and will continue to be in need until more affordable lower home pricing develops, says Business Week.

RESTORING OUTSIDE BEAUTY AND ENHANCING INDOOR COMFORT

For the next couple of years, the building industry in both the commercial and residential markets will need to be focused on the renovation and remodeling of existing buildings. To make older buildings more marketable, exterior changes will be made to create a more contemporary look. During this remodeling process, significant improvements must also be made in the building's energy efficiency. Heating and cooling costs must be reduced and the building's indoor comfort must be maximized.

In residential homes and apartments built in 1972, only 17% of the windows contained insulating glass windows, reports Rick Cunningham, AFG Industries, Inc., at SIGMA's 1991 winter meeting. Commercial buildings built that year had insulating glass units in only 12% of the buildings. In 1990, these percentages changed to 86% and 80% respectively, according to Cunningham. During these past years, both segments of our building industry have shown this dramatic, and continuing, demand for the most energy efficient and comfort-producing glass products.

Today, we have insulating glass units made with new color tint glasses, new solar and heat reflecting glasses and films, and new gas filling. Collectively and individually, the qualities in window's today provide exceptionally high energy savings and comfort not available 10 years ago.

Many of today's residential windows are construction of triple-glazed insulating glass units. Triple-glazed and quadruple-glazed insulating glass units with today's glasses and unit construction makes renovation of energy-losing window areas into glass areas with thermal insulating values equal to, or near equal to, that of adjacent opaque wall construction. (see Figure 1)

Figure 1

1980 IG Product	Winter U (air)*	Winter U (argon)*
Double IG	.49	N.A.
Triple IG	.32	N.A.
Double IG & Reflective	.29 - .44	N.A.
1991 IG Products		
Double IG + Low-E	.32	.28
Triple IG + Low-E	.26	.24
Triple IG + 2 Low-E	.21	.16
Double IG + Refl. + Low-E	.20 - .32	.18 - .28
Double IG + Film	.23	.19
Double IG + 2 Films	.18	.13

(Low-E coatings, reflective coatings and films present a range of U-values)
(N.A. = not available)
* SIGMA IG Manufacturer's Published Literature

WINDOWS THAT BRING WINTER SUN IN WITHOUT LETTING HEAT OUT

A building's heating load in relation to the window area is directly related to the glass product's ability to minimize the outward loss of internally generated heat while controlling the entry of free solar radiant energy.

A change from single-glazing to double-glazing will reduce winter-time heat loss by 56%. A change to a triple-glazed IG unit will reduce this loss by 72%. A triple-glazed IG unit with two lites of Low-E and gas-filled glass will give an 86% reduction of winter heat loss.

SIGMA members now offer insulating glass units with winter U-values equal to many opaque wall constructions – a significant energy-efficient solution to the age-old theory that function outweighs form. (See Figure 2)

Dual and triple insulating glass units with Low-E coated glass and argon filling are the most popular window products used in the home building industry today. Dual, triple and quadruple IG units with Low-E and solar reflective coatings are available to give maximum performance in every geographic location in the United States. Computer analysis can be made of heating and cooling cost benefits relative to more effective glass product selection of each specific proposed building renovation. An investment in these products will result in continuing paybacks in fuel savings night and day, 365 days per year.

Figure 2

Wall Construction	Winter U (air)*	IG Products
4" face brick 4" common brick air space ½" gypsum board	.29	IG + Reflective IG + Low-E + Argon Triple IG + Argon
½" siding ½" sheating air space ½" gypsum board	.23	Triple IG + 2 Low-E IG + Film
½" siding ½" sheating 2 ¾" fiberglass ½" gypsum board	.11	IG + 2 Films + Argon Quad IG + Low-E + Argon

*ASHRAE Handbook of Fundamentals

WINDOWS THAT KEEP SUMMER HEAT OUT WHILE LETTING LIGHT IN

To obtain low air conditioning costs, the transmission of solar radiant energy and the conduction of outdoor air temperature energy must be effectively stopped from entering the building. The glass industry presents a selection of more than 100 different solar reflective glasses to achieve this. These glasses also provide the desired balance of light transmission for indoor lighting.

Insulating glass units with solar reflecting and Low-E coated glasses and argon gas filling will reduce glass area heat gain by 80% over what would enter a building through a lite of clear glass. While very attractive on commercial buildings, the distinguished appearance of solar reflecting glass is too striking for applications in most residential buildings. For heat gain reduction in remodeling residential properties, tinted glass IG units with Low-E coating and argon filling are used which enhance privacy while providing a 65% reduction in heat gain over that of single, clear-glass glazing.

NOT TOO HOT AND NOT TOO COLD: KEEPING IT JUST RIGHT

In single-glazed buildings, office personnel cannot work near windows because the temperature is too hot in the summer and too cold in the winter. As a result, two to four feet of floor area is lost.

In residences, the preferred chair location at the window is compromised because of uncomfortable drafts in the summer and winter.

The high thermal performance IG units discussed in this article also provide total room comfort because the Low-E coated glass maintains the in-door glass temperature near that of the thermostat setting. (See Figure 3) Extreme temperature drafts of the indoor floor area are eliminated which permits total utilization of the space.

Solar reflective and tinted glasses reduce the transmission of the visible sector of the sun's rays eliminating the normally distracting brightness of clear, glass windows. With indoor adjacent walls of light color, window area "glare" is not a problem.

Another very important benefit of today's high-performance IG units is that healthy relative humidity levels can be maintained without window condensation problems.

Figure 3

Glass Product	Temperature (F) Indoor Glass Surface	Condensation Relative Humidity %*
Single	34^o	25
IG Unit	52^o	53
IG + Low-E + Argon	59^o	68
IG + Reflective + Argon	56^o	61
IG + Reflective + Low-E + Argon	61^o	73

(outdoor air temperature = 20^oF, indoor air temperature = 70^oF)
* SIGMA IG Manufacturer's Published Literature

EFFECTIVE GLAZING RENOVATION PROJECTS

On all building reglazing projects, particular attention must be paid to many specific areas of glazing. The new insulating glass units being installed (either in the original sash or in the new sash) with properties to control radiant and sensible heat are much more heat-absorbing than the glass being replaced. The new glass will experience greater thermal stressing. A complete thermal analysis must be made to determine if heat-strengthened glass should be used. The three major factors that need to be addressed in this analysis are: the slow thermally reacting brick and masonry facados, vertical and diagonal outdoor shading and indoor blind locations.

The installation recommendations of the IG manufacturer and of SIGMA should be completely followed with specific attention given to these supplementary details:

- The installation of the window/sash frame must be plumb, level and in one plane. Check the original frame if it is to be reused. If a frame corner is fixed at a plane difference of 1/32" from the rest of the frame, a 1/8" glass unit would experience a 1500 psi stress. (A 1/4" glass unit with a localized edge deflection of 1/64" would also contain a permanent stress of 1500 psi.) This could be the most important contribution to glass breakage at a later time when high-wind load and/or thermal stressing occurs.

- If the window/sash frame is installed with the sill member out of level by 1/16", a 48" wide sash with weep holes at the quarter points could collect one cubic inch of "undrainable" water at that corner. Because of this possibility, one of the three weep holes of the glazing frame should be at the center of the sill and the other two should be at the very corners of the sill-jamb intersection.

  The weep holes should be rectangular which converts the normally recommended 3/8" diameter holes into 1/4" by 7/16" slots. Insure that the 7/16" dimension is exactly flush at the sill glazing channel base. Corner weep holes will assure that all infiltrated water will be drained and also that the drainage marking will be near the jambs and not at the quarter point area of the fascade below.

- The setting blocks should be 1/16" less in width than the sash channel width to prevent misalignment of the block with the unit's two glass edges. The setting blocks (and edge blocks) must be pretested to confirm compatibility with the IG unit's edge sealant. The blocks should be of a material that will limit its compression set upon the specific unit's weight to .020" to .030". Any applicable shear displacement of the IG unit seal will lead to premature failure.

- In compression gasket glazing systems, the minimum pressure of four pounds per linear on the unit's edge must be uniform and remain permanent to assure watertight sealing. The compression set of the gasket must be fully considered.

RENOVATION: A LUCRATIVE AND GROWING MARKET

In today's construction industry, building remodeling represents a very lucrative and growing market, which can be quite profitable for owners, architects, fabricators and glaziers. Renovation can make older buildings more attractive and more marketable at far below new building costs. Both aesthetics and energy efficiency are the improvements that make property desirable to rent, lease or buy. This market is very large and exists in every city in the United States. Seventy percent of the commercial and residential buildings constructed prior to 1970 were glazed with energy inefficient single glazing.

There is overwhelming support for current development of federal and state guidelines for minimum window energy standards for future buildings. Equal – or more – attention should be given to our hundreds of millions of commercial and residential buildings that are well below such standards.

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Newsletter from the Sealed Insulating Glass Manufacturers Association

SG-1000-90

STRUCTURAL LIMITTATIONS OF IG UNITS UNDER UNIFORM LOADS

Wind load is defined as a force uniformly applied to a glass surface. SIGMA recognizes the importance of establishing design charts for use in determining glass strength by the design professional.

When determining an insulating glass unit's wind load capacity, there are three publications U.S. glass manufacturers commonly use. While these three publications show areas of similarity of glass size and thickness per applied load, oftentimes, each method will give a significantly different answer to the same set of conditions. SIGMA, while not specifically endorsing any one of these methods, does recognize its obligation to bring this subject to the attention of the design professional and to its membership. The following information is provided for you to make your own comparisons and conclusions.

On each building project, it is the responsibility of the professional engineer to establish the specific design loads, acceptable probability of breakage and load duration for each project. The project design load is developed in compliance with state and local building codes, the ANSI A58.1 Standard on Minimum Design Loads for Buildings, and in some cases, wind tunnel testing.

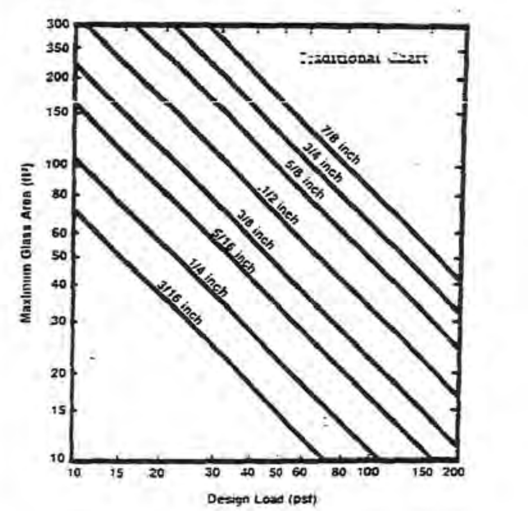
The three methods reviewed in this article include the Model Building Codes, the ASTM Standard E-1300-89 and Glass Thickness Recommendations to Meet Specified One-Minutes Wind Loads, compiled by PPG Industries, Inc., Pittsburgh, PA. While the Model Building Codes are generally the method adopted by local building authorities for glass strength analysis, it does contain a provision that accepts alternate means for adequate glass strength determinations. This provision stirred such a controversy within the industry that both PPG and ASTM developed their own standards which are widely accepted as well. A review of current glass product literature shows that while there doesn't seem to be an overwhelming majority using any one particular method, the design professional must be aware of the similarities and differences in the different methods used.

In this review, only insulating glass units constructed of two monolithic glass lights of the same thickness are studied. Other IG unit constructions and monolithic glass products have similar variances in allowable square foot area per applied load values ccording to the method used.

Methods for Determining Glass Size Per Load

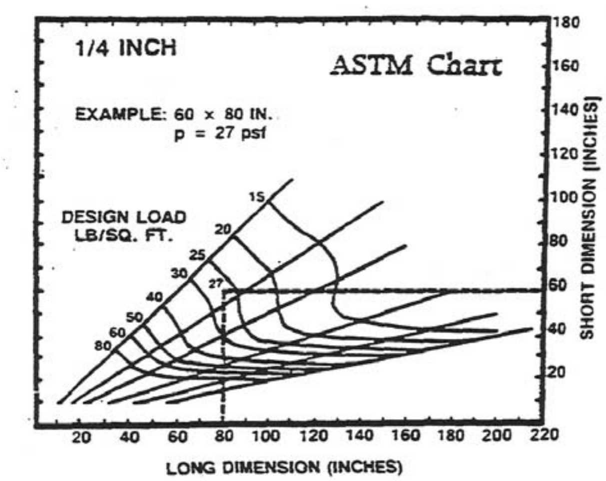
<u>Model Building Code Glass Strength Method</u>

The Model Building Codes present the traditional straight-line charts relating the square foot area of an annealed, monolithic piece of glass of a specific thickness to the maximum one-minute load it can adequately support. For products other than annealed, monolithic glass, the codes present multiplying factors that are applied to the annealed glass values. For annealed insulating glass units, this factor is 1.7 and for tempered insulating glass units (both lights tempered) the factor is 7.6.



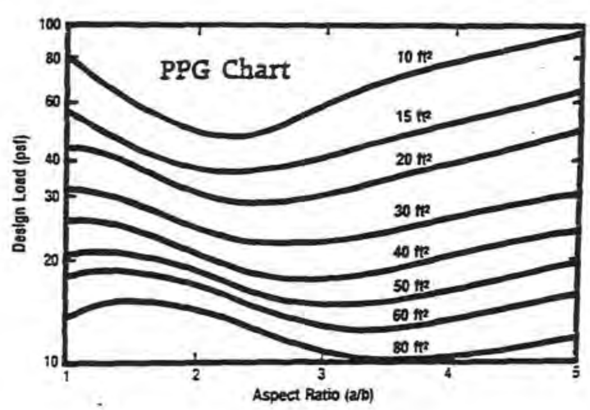
ASTM Glass Strength Method

The ASTM E-1300-85 Standard presents charts relating the width and length dimensions of an annealed, monolithic piece of glass of a specific thickness to the maximum one-minute load it can adequately support. The influence of the glass product's width-to-length size (aspect ratio) is addressed and is of significance. For annealed, insulating glass units, the factor of 1.8 is applied to the annealed, monolithic glass value and a factor of 7.2 for tempered insulating glass units. These factors are those temporarily approved by the ASTM Task Group E06.51.13 at their October 23, 1989, meeting. Multiplying factors for insulating glass units, laminated, heat strengthened and tempered glass are still under study by the ASTM Task Group.



PPG Industries Glass Strength Method

PPG Industries' position on glass strength under load is presented in their publication *Glass Thickness Recommendations to Meet Architect's Specified One-Minutes Wind Load*. PPG does not present factors that can be applied to annealed, monolithic glass values, but instead covers each glass product with its individual chart. As of March 26, 2990, PPG adopted the ASTM E-1300 Standard as their recommendation for annealed, monolithic glasses. For all other glass products, PPG continues to recommend the glass product charts presented in their above mentioned publication. These PPG charges incorporate the influence of the glass product's long-to-short dimensional ratio.



INSULATING GLASS UNITS

ANNEALED INSULATING GLASS UNITS

Glass	Sq. ft. Area	Aspect Ratio	Bldg Code PSF	ASTM E-1300 PSF	PPG PSF
ss+ss	4	1	64	86	-
		2	64	72	-
		3	64	66	-
		4	64	90	-
		5	64	90	-
	6	1	54	61	-
		2	54	54	-
		3	54	48	-
		4	54	54	-
		5	54	55	-
1/8+1/8	10	1	68	59	73
		2	68	49	52
		3	68	45	37
		4	68	45	45
		5	68	65	60
	15	1	46	49	48
		2	46	38	40
		3	46	31	29
		4	46	31	32
		5	46	36	39
3/16+3/16	15	1	83	76	95
		2	83	67	54
		3	83	61	60
		4	83	72	75
		5	83	56	92
	20	1	63	58	66
		2	63	47	46
		3	63	43	46
		4	63	54	54
		5	63	65	67
¼ + ¼	20	1	90	72	88
		2	90	65	62
		3	90	67	62
		4	90	90	80
		5	90	99	98
	40	1	46	32	35
		2	46	31	90
		3	46	25	26
		4	46	25	29
		5	46	27	34

TEMPERED INSULATING GLASS UNITS

Glass	Sq. ft. Area	Aspect Ratio	Bldg Code PSF	ASTM E-1300 PSF	PPG PSF
1/8+1/8	10	1	304	238	350
		2	304	194	290
		3	304	180	300
		4	304	180	270
		5	304	259	300
	15	1	205	198	250
		2	205	152	205
		3	205	124	220
		4	205	124	200
		5	205	144	215
3/16+3/16	15	1	372	302	490
		2	372	266	395
		3	372	245	350
		4	372	288	350
		5	372	223	440
	20	1	281	230	365
		2	281	187	315
		3	281	173	295
		4	281	216	300
		5	281	259	350
¼ + ¼	20	1	342	288	520
		2	342	259	450
		3	342	266	395
		4	342	360	380
		5	342	396	470
	40	1	205	173	220
		2	205	137	285
		3	205	122	250
		4	205	144	220
		5	205	173	255

Differences Between Methods

While thest three methods do share some similarities, they are widely different in size requirements and aspect ratio allowed with respect to annealed and tempered glass. Following are observations that can affect the type of unit you choose.

Annealed Glass IG Units

The Building Code method permits the use of larger size units (except some single strength glass units) at the same total load. However, the ASTM method is the most restrictive. When a manufacturer uses this method, 1/8" glass units will be 4 to 5 square feet smaller than allowed by the Building Code method.

The aspect ratio of a product produces a variance of 26 to 42 percent in load bearing capabilities. Generally, units with an aspect ratio of 1.0 and 5.0 are the strongest and units with the aspect ratio of 3.0 the weakest. The aspect ratio influence is more restrictive with the PPG method.

Tempered Glass IG Units

Generally, the PPG method permits larger size tempered glass IG units per applied load. The ASTM method, with its current multiplying factor, however, is the most conservative. Using this method, IG units are capable of supporting 5 to 40 percent smaller loads than the same unit under the Building Code Method.

In Conclusion

The traditional straight line charts found in the Building Code method with the single multiplying factors have served the industry well. A greater understanding of glass strength through continuing studies by glass manufacturers, independent research organizations and standard writing groups must be thoroughly evaluated to update and unify the glass industry on this important subject. It appears the industry will adopt the new ASTM charts, but people must understand the differences. It may be premature at this time to use the new charts until they are finally adopted by the code groups.

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SIGMA-Gram

Newsletter from the Sealed Insulating Glass Manufacturers Association

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THROUGH THE LOOKING GLASS:
Architects Reflect on the Past, Present and Future of Glass

"In this high-tech era, there's more to windows than yesteryear's wooden frame and glass affairs. One major manufacturer has 8,000 sizes, variations and prices," said *Business Week* Magazine in an article on insulating glass.

Glass has evolved remarkably since the early days when builders thought of it merely as a material that let in light. When Sir Joseph Paxton build London's Crystal Palace entirely of glass in 1850, the world was amazed at this revolutionary use of an ordinary material.

To get an overview of where the glass industry is headed today, the Sealed Insulating Glass Manufacturers Association (SIGMA) conducted an informal survey of architects to get their insights on where the industry has been and where it's going.

> *Glass Industry reported in an editorial in the December 1990 issue that glass insulation helps protect the environment by saving America about 4 billion barrels of oil a year.*

Two significant points came across strongly. One is that glass is stimulating to each designer in a different way. Its myriad applications and intriguing qualities will continue to fuel architectural creativity for years to come.

Another important issue that surfaced was the responsibility architects feel toward conserving energy. *Glass Industry* reported in an editorial in the December 1990 issue that glass insulation helps protect the environment by saving America about 4 billion barrels of oil a year – the equivalent of about 3,000 oil super tankers. Today's architects are constantly searching for the best way to protect our environment.

From a Punctured Opening to an Element of Beauty

Joseph Banks of Banks/Eakin Architects in Chicago says glass was just a punctured opening in masonry until steel structures were built after the Second World War. According to Banks, once steel skeletons could be built with steel frames endless possibilities for glass opened up.

> *It's transparent, reflective, patterned and artful. It's decorative, functional and effective at creating form and illusion.*

"At that point glass architecturally changed a lot from the traditional window. It has so many aesthetically pleasing and inherently good qualities," says Banks.

Banks says 10 years ago glass windows and glass spandrels were showing up everywhere. But he feels today there is more of a balance between open walls and solid, non-transparent walls so buildings function well.

"Glass still isn't as efficient as a well-insulated wall", says Banks. "But they are always coming out with more efficient glass."

Emerging as an Expression of Architecture

Architect Gerald Horn of Chicago's Holabird & Root says until the '60s architecture was technology exploring technology. He feels world-renowned architect Mies Van Der Rohe changed that when he started showing off structure and exploring the expression of the structure", says Horn.

The energy crunch of the late '60s and '70s affected the use of glass because builders didn't find it energy efficient, according to Horn. And he also felt that glass got into a lot of trouble with mirror glass.

> *But today with the low-E glass, architects have the freedom to use glass as they please – it's so close to where we want it in terms of efficiency and quality.*

"Mirror glass solved a lot of problems and created a lot of problems", says Horn. "That lasted until about five years ago. With today's low-E glass and gas-filled glass, architects are able to achieve those types of expressions once again."

Horn designed Chicago's American Bar Association building, which is an all glass building that went up six years ago.

"The only glass available to meet our needs at that time was a dark grey glass – which had the qualities we liked in mirror glass without having to use mirror glass", says Horn. "But today with the low-E glass, architects have the freedom to use glass as they please – it's so close to where we want it in terms of efficiency and quality."

Glass Launches Modern Architecture

A young Chicago architect working on the plans for the city's famous Marina towers remembers how the building's architect, Goldberg, was influenced at that time by the period of "brutalism."

"Everything had to be massive and strong", recalls Joe Barrowman. "Then Mies Van Der Rohe came along and started using glass to make buildings light and lacy. I believe glass started modern architecture. Look at the famous Chicago Window – the beautiful bay windows you still see downtown."

Barrowman says if he didn't feel so limited today by issues of energy conservation, he would use much more glass in his designs. "I would just open up great vistas of view and let my imagination run freely."

Fighting off Sun and Thriving on Scenery

Challenged by the salt air and the bright sun, Florida Architect Herbert Ross Savage of Herbert Ross Savage AIA faces a different set of criteria when building with glass.

"We get squeamish using a lot of glass in all that bright Florida sun", says Savage. "In fact, I put up a bank building that was all mirror glass, but we put in a masonry wall behind it to keep out the heat."

> *What if you were looking down from an airplane on a subzero degree day and you saw some man in his swimsuit in his backyard gardening – oblivious to the subfreezing temperatures.*

However, Savage says the mirror worked powerfully in reflecting the many days of blue skies and beautiful clouds. "At the right time of day, in the right light, you hardly see the building", says Savage. "It blends right into the environment instead of jutting out like an obstacle."

Savage designed Marriott's Marco Beach Hotel on Marco Island. Large sheets of glass were used in the design to show off the beautiful ocean views, but the structure was basically built out of concrete and stucco.

Savage says he's disappointed that glass hasn't been developed better for marketing goods. "I grew up in Miami in the '30s and I remember Burdines Department Store had windows that curved up and had a black top – similar to a shadow box. When we looked in the window, we didn't see reflections, we saw the product.

"Here it is 1990 and we still can's see the product in a store window", he says. "All we see is the reflections of the streets and poles."

Savage's ultimate dream for glass is to be able to glaze in a yard by some transparent method. "Imagine living in Ohio or Pittsburgh and being able to cover your whole yard with a semi-circle that would keep out the wind, cold and rain. What if you were looking down from an airplane on a subzero degree day and you saw some man in his swimsuit in his backyard gardening – oblivious to the subfreezing temperatures."

A Wonderful Material

New York's Der Scutt of Der Scutt Associates says architects think twice nowadays about where they construct a glass building. They are concerned with blending the building's materials into the already existing environment.

"Ten years ago, we would think nothing of putting up a glass building anywhere", says Scutt. "Today I see architects returning to the more traditional styles. Returning to the '20s and '30s is very voguish right now."

"But I don't promote that thinking", says Scutt. "To me modern architecture is not dead."

Scutt feels energy problems are with us forever and that we must be responsible to the limits imposed by energy. He says in Europe many buildings have three layers of glass and are more energy efficient.

However, Scutt is inspired by the current use of glass in today's world. "Glass is a very wonderful material", says Scutt. "And in the hands of the right architect it can make a very beautiful building."

Fifty-Year Overview

As a foundation for the ideas presented by the architects, it is interesting to review the following list of the "most significant events that have taken place in the glass industry in the last 50 years" as outlined at the 50th Session of the Glass Problems Conference by speaker Dr. Fay v. Tooley. These events include:

- Development of the float glass process.
- Development of the continuous textile glass fiber process.
- Introduction and growth of plastic containers.
- Emergence and growth of electric meter technology.
- The growth of computer use in glass production.
- Continuous development of the I.S. (Independent Section) Machine.
- Development of glass optical fibers.

- Environmental concerns: The Clean Air Act, Clean Water and Hazardous Disposal Acts.
- Developments in glass recycling.
- The oil embargo leading to energy concern and in some cases raw material concern.
- The phenomena of company mergers and acquisitions.
- The development of a considerable number of new glass types: nonsilicate, chalcogenide, oxynitride, fluoride, etc. and the solgel method of glass formation.

IGMA-Gram

Newsletter from the Insulating Glass Manufacturers Alliance

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THE LANGUAGE OF SEALED INSULATING GLASS UNITS

All industries have their own terms and phrases. Sometimes these terms have a totally different meaning from one industry to another, even though they are spelled alike and sound alike. For instance, glazing to a baker is quite different from glazing to a construction worker. Even within an industry, new products, new usages and improved technology can bring on new meaning or create new terminology.

Active Solar Heat Gain – Solar heat that passes through a material and is captured by mechanical means.

Adhesion – That property of a sealant / compound, which measures its ability to bond to the surface, which it is applied.

Adhesion Failure – The pulling away of a sealant / compound from the surface it is applied to resulting in water penetration.

Air Infiltration – the amount of air that passes between a window sash and frame, or a door panel and frame; for windows it is measured in terms of cubic feet of air per minute per square foot of area, and for doors it is measured in terms of cubic feet of air per minutes, per foot of crack.

Air Space – The space in the cavity between two panes of glass in an insulated glass unit.

Aluminum Spacer – A rectangular or contoured hollow aluminum bar filled with a desiccant (or moisture-absorbing material) that is traditionally used to separate the panes in double-pane glass units.

Annealed Glass – Standard sheet of float glass, which is heat-treated to increase its impact resistance.

Anodized Aluminum – Aluminum that is treated by electrolysis to develop a finished surface (an extremely hard, noncorrosive oxide film). The electrochemical process produces an anodic coating by converting aluminum into aluminum oxide by electrolytic action. The resulting finish may be either clear or colored, and is an integral part of the aluminum.

Anti-reflective Coating – A transparent coating, typically 150 nm thick, which reduces surface reflectance by using destructive interference between light reflected at the substrate surface and light reflected at the coating surface.

Argon Gas (argon filled) – An inert, nontoxic gas placed between glass panes in insulated glass units in order to improve the insulating value of sealed glass units.

Bead – A sealant / compound after application in a joint. Also a molding or stop used to hold the glass product in position.

Bite – The dimension by which the edge of a glass product is engaged into the glazing channel.

Block – Rectangular, cured sections of neoprene or other approved material, used to position the glass product in the glazing channel.

Breather (Tube) Units – An insulating glass unit where a tube or a hole is factory-placed into the unit's spacer to accommodate elevation of pressure differences encountered in shipping. These tubes or holes are to be sealed on the job-site prior to unit installation.

BTU – An abbreviation of British Thermal Unit that defines the amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit.

Butt Glazing – The installation of glass products where the vertical glass edges are without structural supporting mullions.

Capillary Tube Units – An insulating glass unit where a very small metal tube of specific length and inside diameter is factory-placed into the unit's spacer to accommodate both the pressure differences to the point of installation and also the pressure differences encountered daily after installation. Capillary tubes are not sealed after installation.

Certified I.G. Unit – An insulating glass unit constructed like a unit test model, which has successfully passed the ASTM E 773 / E 774 or ASTM E 2188 / E 2189 / E 2190 tests of insulating glass seal durability performance at specific levels. (Pursuant to the administrative guidelines of a certification program.)

Channel Glazing – The installation and sealing of glass products into U-shaped glazing channels employing removable stops.

Chromogenic Glazing – A broad class of switchable glazings including active materials (i.e.: electrochromic) and passive materials (photochromic and thermochromic).

Clear Glass – Architectural clear glass is mostly of the soda-lime-silica type, and composition varies between manufacturers, but is generally 70 - 74 percent silica, 5 - 12 percent lime, and 12 - 16 percent soda, with small amounts of magnesium, aluminum, iron, and other elements.

Coating – A thin layer applied to the surface of a glass in either a chemical deposition technology (i.e.: vapor, liquid, etc.) or a vacuum sputtering process. After application it is converted to a solid protective, decorative, or functional adherent film.

Cohesive Failure – The splitting and opening of a sealant / compound within its body, resulting in water penetration.

Compound – A formulation of vehicle, fillers and polymer(s) producing an elastomeric sealant.

Condensation – Moisture that forms on surfaces when they are colder than the dew point.

Conduction – The transfer of heat through matter, whether solid, liquid or gas.

Conductivity, Thermal – The time rate of steady state heat flow through a unit area of homogenous material induced by a unit temperature gradient in a direction perpendicular to that unit area.

Convection – The transfer of heat through a liquid or gas, when that medium hits against a solid surface.

CR – Condensation Resistance index; an indication of a window's ability to resist condensation developed by NFRC (National Fenestration Ratings Council). The higher the CR, the less likely condensation is to occur.

CRF – Condensation Resistance Factor; an indication of a window's ability to resist condensation developed by AAMA (American Architectural Manufacturers Association). The higher the CRF, the less likely condensation is to occur.

Curing Agent – One part of a two-part sealant which, when added to the base material, causes it to vulcanize by chemical reaction.

Curtain Wall – An external, nonbearing wall that is intended to separate the exterior and interior environments.

Dead Loads – Load force due to glass weight.

Desiccants – Porous crystalline substances used to absorb moisture and solvent vapors from the air space of insulating glass units. (More properly called absorbents.)

Design Wind Load – The wind-load pressure a product is required, by the specifier, to withstand in its end use application.

Dew Point – The temperature above 32^{o}F at which visible water vapor or other liquid vapor begins to deposit on the air-space glass surface of a sealed insulating glass unit in contact with the measuring surface of the dew-point apparatus.

Diffusivity, thermal – Thermal conductivity per unit of heat capacity.

Distortion – The optical effect due to the variation of sheet glass thickness.

Double-Glazed Units – Units of two lites of glass and one air space.

Dual-Sealed Units – Sealed insulating glass units fabricated with an inner seal and an outer secondary seal. Generally, each of the two seals has been selected for its special performance characteristic, i.e.: adhesion and moisture vapor transmission properties.

Durometer – a gauge to measure the hardness of an elastomeric material.

Edge Clearance – Nominal spacing between the edge surface of the glass product and the glazing channel base.

Effective Thermal Conductivity – The combined effects of conduction, convection, and radiation in fluid-filled (gas-filled) enclosures and cavities, converted into an apparent or effective conductivity of a solid.

Elastomeric – Having the property of returning to its original shape and position.

Electrochromic(s) (glazing) – Glazing with optical properties that can be varied continuously from clear to dark with a low-voltage signal. Ions are reversibly injected or removed from an electrochromic material.

Emissivity – the relative ability of a surface to radiate heat, with emissivity factors ranging from 0.0 or (or 0 percent) to 1.0 (or 100 percent).

Emittance – Heat energy radiated by the surface of a body, usually measured per second, per unit area.

Equivalent Combined Glass Load – Combination of the instant applied load of wind and the factored long term loading of glass weight and snow accumulation.

Etch – To attack the surface of glass with hydrofluoric acid or other agents, generally for marking or decoration.

Evacuated Glazing – An insulating glazing composed of two glass layers, hermetically sealed at the edges, with a hard vacuum between (< 10-3 Pascals) to eliminate convection and conduction. A spacer system (commonly referred to as "pillars") throughout the surface of glass (rather than just at the edges) is needed to keep the panes from touching.

Exterior Glazed – Glass set from the exterior of the building.

Failed I.G. Unit – An installed unit failure exhibits permanent material obstruction of vision through the unit due to accumulation of dust, moisture or film on the internal surface of the glass. Surface numbers 2 or 3 in dual-pane units; surface numbers 2, 3, 4 or 5 on triple-pane units.

Flat Glass – A general term covering sheet glass, plate glass, float glass, window glass, and various forms of rolled glass, and named according to the method used in its manufacture. *See also* Float glass, Plate glass, Sheet glass.

Float Glass – Transparent glass with flat, parallel surfaces formed on the surface of a pool of molten tin.

Foam Spacer – Nonconductive, foam material (often closed-cell silicone foam) used to separate the double and triple-pane insulating glass units; improves the thermal performance of the window.

Fogged Unit – A permanent deposit of contaminates on the interior glass surfaces of an insulating glass unit.

Fogging – A deposit of contamination left on the inside surface of a sealed insulating glass unit due to extremes of temperatures or failed seals.

Frost Point – The temperature below 32^{o}F at which visible frost begins to deposit on the air-space surface of a sealed insulating glass unit in contact with the measuring surface of the front-point apparatus.

Fully Tempered Glass – Transparent or patterned glass with a surface compression of not less than 10,000 psi or an edge compression of not less than 9,700 psi.

Gas Filled Units – Insulating glass units with a gas other than air in the air space to decrease the unit's thermal conductivity U-value and to increase the unit's sound insulating value.

Gas Retention – The ability of a sealed insulating glazing unit to retain its original gas-filled composition. In the long term, diffusion through frame and edge-seal materials allows air to progressively replace the original gas(es).

Gasket – Pre-formed shapes of rubber, or rubber-like compositions, used as the weather seal. Also, a spacer for supplemental application of a sealant.

Gasochromic Glazing – Glazing which uses the phenomenon of chromism due to tin injection / ejection to color the window. The application of gas flow transporting ions to the surface (catalyst), which changes solar and visible transmittance. See also Switchable glazing.

Glass – A transparent, brittle substance formed by fusing sand with soda or potash or both; it often has lime, alumina or lead oxide.

Glazing – The installation and weather sealing of a glass product in a prepared sash opening.

Glazing Bead – A strip surrounding the edge of the glass in a window or door; applied to the sash on the outside, it holds the glass in place.

Glazing Channel – a three-sided, U-shaped sash detail into which a glass product is installed and retained by a removable stop.

Glazing Channel Width – the measurement between the stationary stop and the removable stop.

Hard Coat(ing) – A low-emittance (low-e), thin-film surface coating on sheet glass which is deposited at a high temperature during the final stage of glass production. It is resistant to abrasion and attack by moisture, atmospheric pollutants, etc. *See also* Pyrolytic coating.

Heat Gain – Instantaneous rate of heat gain at which heat enters into and / or is generated within a space. Latent heat gain occurs when moisture is added to the space (from occupants or equipment). Sensible heat gain is added directly to the space by conduction, convention, and / or radiation.

Heat Loss – The transfer of heat from inside to outside by means of conduction, convection, and radiation through all surfaces of a building.

Heat Loss Rate – The rate at which heat is lost from a system or component of a system, per degree of temperature difference between its average temperature and the average ambient air temperature

Heat Mirror™ – A thin, transparent-coated (low-e) polymer film that is inserted between double or triple glazing, which permits transmission of visible light but reflects far-infrared (and sometimes near-infrared) radiation. Heat Mirror™ is a commercial trademark of Southwall Technologies for their proprietary soft-coated, low-e polyester glazing films.

Heat-strengthened Glass – Transparent or patterned glass with a surface compression of not less than 3,500 psi or greater than 10,000 psi, or an edge compression of not less than 5,500 psi.

Heat-absorbing Glass – Glass (usually tinted) formulated to absorb an appreciable portion of solar energy.

Heat-treated Glass – A term sometimes used for both fully tempered and heat-strengthened glass.

High-transmission Glass – Glass that transmits an exceptionally high percentage of visible light.

Humidity, Absolute – The mass of water vapor per unit of volume.

Humidity, Relative – The percentage of moisture in the air in relation to the amount of moisture the air could hold at that given temperature.

Impact Resistance – The ability to withstand mechanical blows or shock without damage seriously affecting the effectiveness of the material or system.

Inert Gas – Refers to the use of chemically nonreactive gas(es) within the cavity of a sealed insulating glass unit for the purpose of reducing conductive / convective heat transfer. *See* Gas filled units.

Insulating Glass (IG) Insulating Glass Unit (IGU) – A combination of two or more panes of glass with a hermetically sealed air space between the panes of glass, separated by a spacer. This space may or may not be filled with an inert gas, such as argon.

Interior Glazing – Glass set from the interior of the building.

Interior Glazing Depth – The measurement from the bottom of the glazing channel to the top of its stops.

Internal Muntins – Decorative grid installed between the glass lites that do not actually divide the glass.

Krypton – An inert, nontoxic gas used in insulating windows to reduce heat transfer.

Laminated Glass – Two or more lites of glass bonded together with a plastic interlayer.

Light – A unit of glass in a window or door; it is enclosed by the sash or by muntins and bars – also called pane.

Light Reducing Glass – Glass formulated to reduce the transmission of visible light.

Lite – Another term for a glass product.

Live Load – Load force due to weight on non-permanent attachments; people, glazing rigs, washing rigs.

Low Emissivity Glass – Glass with a transparent metallic or metallic oxide coating applied onto or into a glass surface, which reflects long-wave infrared energy and thus improves the U-value.

Low-conductance Spacers – An assembly of materials designed to reduce heat transfer at the edge of an insulating window. Spacers are placed between the panes of glass in a double or triple-glazed window.

Low-e (low-emittance) Coating – A microscopically thin (less than 100 nm) metal, metal oxide, or multilayer coating deposited on a glazing surface to reduce its thermal infrared emittance and radiative heat transfer. Near-infrared emittance may also be reduced depending on whether solar heat is to be rejected or admitted. Low-emissivity glass is used to increase a window's insulating value, block heat flow, and reduce fading.

Metal Spacers – Roll-formed metal shapes used at the edges of an insulating glass unit to provide the desired spacing of the glasses; metal spacers allow areas for sealant applications and contain desiccants.

Modulus – Stress at a given strain. Also tensile strength at a given elongation.

Moisture Vapor Transmission (MVT) – The steady water vapor flow in unit time through a unit area of a body, normal to specific parallel surfaces, under specific conditions of temperature and humidity at each surface.

Mullion – A horizontal or vertical member that holds together two adjacent lites of glass or sashes, or curtain-wall sections.

Multiple-glazed Units – Units of three glass lites (triple glazed) or four glass lites (quadruple glazed) with two and three air spaces respectively.

Muntins – Horizontal or vertical bars that divide the sash frame into smaller lites of glass. Similar to mullions but smaller in dimensions and weight.

Natural Convection – A heat transfer process involving motion in a fluid (such as air) that is caused by a difference in the density of the fluid and the action of gravity. This is an important part of heat transfer from the glass surface to room air.

Needle Glazing – application of a small bead of sealant / compound at the site line by a nozzle gun.

Pane – See Light, also Lite.

Passive Solar Heat Gain – Solar heat that passes through a material and is captured naturally, not by mechanical means.

Patterned Glass – Rolled glass having a distinct pattern on one or both surfaces.

Performance (energy) – The thermal, solar, and visual properties of a product influence the building energy balance due to solar gains, heat loss, and daylight, and require auxiliary energy from artificial lighting, heating, and cooling; ventilation energy (fans) may also be affected. Therefore, a product has an impact on the overall primary energy use in a building.

Permeability – the time rate of water vapor or gas transmission through a unit area of the material of unit thickness induced by unit vapor pressure difference between two specific surfaces under specified temperature and humidity conditions.

Permeance – The time rate of water vapor or gas transmission through a unit area of a body, normal to specific parallel surfaces, under specific temperature and humidity conditions.

Photochromic Glazing, Photochromics – Glazing which changes its thermal, solar, and visible transmittance in response to outdoor illuminance or ultraviolet (UV) radiation. *See also* Switchable glazing.

Photovoltaic – A device that produces electricity (voltage) directly from sunlight (photons).

Plastic Film – A thin, plastic substrate sometimes used as the inner layers in a triple or quadruple-glazed window.

Plate Glass – Flat glass with surfaces that are essentially plane and parallel; it is formed by a rolling process, ground, and polished on both sides. It is available in thicknesses varying from 1/8" to 1-1/4" (3.2 mm to 31.8 mm), but has been replaced by float glass.

Primary Sealant – A sealant applied to the inner shoulders of a spacer with its principle purpose to minimize moisture, gas and solvent migration into the unit's air space.

Priming – Sealing of surfaces to promote adhesion of sealants.

Purlins – Structural members, generally horizontal, in slope glazing frames.

Pyrolytic Coating – A low-e, thin-film coating applied at high temperature. *See also* Hard coating.

Rabbet – A two-sided, L-shaped recess in a sash frame to receive glass products. Addition of a removable stop will convert it to a glazing channel.

Radiation – Energy released in the form of waves or particles, due to a change in temperature within a gas or vacuum.

Rafters – Structural members; vertical in slope glazing frames.

Reflectance – The fraction of incident radiation upon a surface that is reflected from that surface.

Reflection – The process by which incident flux leaves a surface or medium form the incident side, without change in frequency.

Reflective Coated Glass – Glass with metallic or metallic oxide coatings applied onto or into the glass surface to provide reduction of solar radiant energy, conductive heat energy and visible light transmission.

Reflectivity – The reflectance of a microscopically homogeneous sample with a clean, optically smooth surface and of thickness sufficient to be completely opaque.

Relative Heat Gain – An energy comparison factor for glass products combining the radiant and conductive heat gas in under specific conditions, (200 BTUs times the shading coefficient + 14 degrees times the summer U-value).

Relative Humidity – The percentage of moisture in the air in relation to the amount of moisture the air could hold at that given temperature. At 100 percent relative humidity, moisture condenses and water droplets are formed.

R-value – The resistance of conductive heat energy transfer in one hour through a one-square foot area of a specific insulating glass unit assembly for each one degree Fahrenheit temperature difference between the indoor and outdoor air. It is the reciprocal of U-value; R = 1/U.

Safety Glass – Glass constructed, treated, or combined with other materials to reduce the likelihood of injury to persons in the broken or unbroken state. Types of safety glass include laminated safety glass, tempered glass, and wire glass.

Sash – A frame into which glass products are glazed, i.e.: the operating sash of a window.

Sealant Spacer – A permanent adhesive sealant extrusion, which may contain a structural metal insert and a pre-compounded desiccant.

Sealants[1] – compounds used to adhere and provide weather tight installation of glass products.

Sealants[2] – (For I.G. Units) Formulated elastomeric compounds of specific application and vapor transmission properties as well as controlled adhesion, cohesion and resiliency properties.

Sealed Insulating Glass Units – Units constructed of two or more lites of glass separated and hermetically sealed to spacer frames at the glass edges with the enclosed air changer(s) dehydrated at the plant's atmospheric pressure.

Secondary Sealant – A sealant applied into the exterior glass-spacer cavity to provide elastic, structural bonding of the assembly, in single-sealed units, this sealant also has low gas and moisture vapor transmission property to achieve effective unit performance.

Setting Blocks – Rectangular, cured extrusions or neoprene rubber or other approved material on which the glass product bottom edge is placed on glazing to effectively support the glass' weight.

Shading Coefficient – The ratio of the rate of solar heat gain through a specific glass unit assembly to the solar heat gain through a single lite of 1/8" clear glass in the same situation.

Sheet Glass – Flat glass made by continuous drawing and whose surface has a characteristic waviness. Because of the long usage of the term, much thin float glass is still incorrectly referred to as sheet glass.

Shore Hardness – Measurement of the hardness of a cured elastomeric material by means of a durometer hardness gauge.

Sight Line – Imaginary line around the perimeter of a glazed glass product defined by the top edge of stationary and removable stops, or the line where the glazing sealant or gasket contacts the glass.

Single-glazed, Single Glazing – Glazing that is just one layer of glass or other glazing material (as opposed to sealed insulating glass which offers far superior insulating characteristics).

Single-sealed Units – Sealed insulating glass units where the structural bonding and moisture sealing is accomplished by a single seal at the edge.

Skylight – A glass and frame assembly, which is installed into a roof of a building.

Sloped Glazing – A glass and framing assembly that is sloped more than 15 degrees from the vertical and essentially forms the entire roof of the structure. This is generally a single-slope construction. Also, any glazed opening in a sloped roof or wall, such as a stationary skylight or fully operable roof window.

Sloped Glazing – Any installation of glass that is at a slope of 15 degrees or more from vertical.

Snow Load – Load force due to snow accumulation.

Soft Coat(ing) – Generally refers to silver-based, low-e coating. So called due to its susceptibility to damage through abrasion. The coating generally consists of a multilayer structure of alternate dielectric and thin transparent metal layers which are deposited in a vacuum chamber. Also known as *sputtered coating.*

Solar Energy – Thermal radiation from the sun; as measured by short radiation wavelengths, less than three microns long.

Solar Energy Absorptance – The percentage of the solar spectrum energy, (ultra violet, visible and near infrared) from 300 to 3,000 nanometers, that is absorbed by the glass product.

Solar Energy Transmittance – The percentage of the solar spectrum energy (ultra violet, visible and near infrared) from 300 to 3,000 nanometers that is directly transmitted through the glass product.

Solar Heat Gain – Heat from solar radiation that enters a building.

Solar Heat Gain Coefficient (SHGC) – The fraction of solar radiation admitted through a window or skylight, both directly transmitted and absorbed, and subsequently released inward. The solar heat gain coefficient has replaced the shading coefficient as the standard indicator of a window's shading ability. It is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits, and the greater its shading ability. SHGC can be expressed in terms of the glass alone or can refer to the entire window assembly. For near-normal incidence only, SHGC = 0.86 x SC. *See also* Shading Coefficient (SC).

Sound-insulating Glass – Glazing that is fixed on resilient mountings and separated so as to reduce sound transmission. Also known as *sound-resistive glass.*

Spacer – The linear object that separates and maintains the space between the glass surfaces of insulating glass.

Spacer Corners – Specific methods used in joining the spacer lengths into spacer frames including interlocking keys, bending, soldering or welding.

Spacer Depth – That dimension of the spacer that is measured perpendicular to the glass surface.

Spacer Width – That dimension of the spacer that is measured perpendicular to the glass surface and establishes the unit's air space.

Spacers (Shims) – Small blocks of neoprene, or other approved material, placed on each side of the glass product to provide glass centering, maintain uniform width of sealant bead, and prevent excessive sealant distortion.

Spandrel – That portion of the exterior wall of a multi-story commercial building that covers the area below the sill of the vision glass installation and above the head of the glass installation below.

Spandrel Glass – Architectural glass that is used in spandrel panels.

Spectrally Selective Coating – A low-e coating with optical properties that are transparent to some wavelengths of energy and reflective to others. Typical spectrally selective coatings are transparent to visible light and reflect short-wave and long-wave infrared radiation.

Spectrally Selective Glazing – A specially engineered low-e coated or tinted glazing whose optical properties vary with wavelength. *See* Spectrally selective coating *and* Spectrally selective tint.

Spectrally Selective Tint – A tinted glazing with optical properties that are transparent to some wavelengths of energy and reflective to others. Typical spectrally selective tints are transparent to visible light and reflect short-wave and long-wave infrared radiation.

Stops – the stationary lip of the back of the glazing channel and removable molding (retainer) at the front of the glazing channel.

Structural Glass – (1) Flat glass that is usually colored or opaque and frequently ground and polished, used for structural purposes. (2) Glass block, usually hollow, that is used for structural purposes.

Structural Glazing – Glazing which is part of the structural design of the facade of a building.

Structural Glazing Gaskets – Cured elastomeric channel-shaped extrusions used in place of a conventional sash to install glass products onto structurally supporting sub-frames with the pressure of sealing exerted by the insert of separate lock strip wedging splines.

Structural Silicone Glazing – A system in which the glass product is bonded to the framing members of a curtain wall utilizing a structural silicone adhesive / sealant without the presence of outdoor retainers or stops.

Sunlight – The portion of solar energy which is detectable by the human eye; it accounts for about 44 percent of the total radiation wavelength spectrum.

Surface Coating – The deposition of a thin-film coating on a surface.

Suspended Film – Polymer-based, optically clear glazing layer mounted between glass layers in a multiple-glazed system.

Suspended Film Insulating Glass Unit – I.G. unit manufactured with a light and energy controlling film suspended within the air space.

Suspended Glazing – Glazing system suspended from above. This innovation, first achieved in projects of the 1960s, made possible continuous glass facades, without mullions.

Switchable Glazings – Glazings with optical properties that can be reversibly switched from clear to dark or reflective with the application of an external stimulus, e.g.: heat, light, electric signal, etc. Also known as *dynamic glazing. See also* Electrochromic glazing, Photochromic glazing, *and* Gasochromic glazing.

Tempered Glass – Treated glass that is strengthened by reheating it to just below the melting point and suddenly cooling it. When shattered, it breaks into small pieces.

Since these particles do not have the sharp edges and dagger points of broken annealed glass, tempered glass is regarded as a safety glass and safety glazing material. Tempered glass is also approximately five times stronger than standard annealed glass. The glass must be cut to size and have any other processing (such as edge polishing and hole drilling) completed before being subjected to toughening, because attempts to work the glass after tempering will cause it to shatter. Also known as *toughened glass.*

Thermal Barrier, Thermal Break – An element, made of a material with relatively low thermal conductivity, which is inserted between two members having high thermal conductivity in order to reduce the heat transfer. Such elements are often used in aluminum windows.

Thermal Conductance (C) – The same as thermal conductivity except that thickness is "as stated' rather than one inch.

Thermal Conduction – The mode of heat transfer through a material by molecular contact. Heat flows from a high-temperature area to one of lower temperature.

Thermal Conductivity (k) – The heat transfer property of materials, expressed in units of power per area and degree of temperature (e.g.: BTU-per-hour per inch of thickness per square foot of surface per one degree F temperature difference).

Thermal Emissivity – Similar to thermal emittance, except that the suffix "-ivity" refers to a property of general material, while "-ance" refers to a specific material with a certain thickness, surface finish, etc.

Thermal Emittance – The ability of a surface to emit long-wave radiation relative to that of a perfect black body. Also known as the *long-wave infrared emittance.* A perfect black body has an emittance equal to 1.0, while a perfect reflector has an emittance equal to zero.

Thermal Mass – The mass in a building (furnishings or structure) that is used to absorb solar gain during the day and release the heat as the space cools in the evening.

Thermal Radiation – The heat transfer by radiation from surfaces at or near the room temperature (i.e.: wavelengths in the range 2.5–50 microns). It is often referred to as far IR radiation or long-wave IR radiation.

Thermal Resistance – A property of a substance or construction which retards the flow of heat; one measure of this property is R-value.

Thermal Stress – Stress caused by the temperature differential across a glazing layer; e.g.: for a tinted or switchable glazing in its darkened state, the sunlit side of the glazing will be hotter than the reverse side.

Tinted Glass – Body colored glass of specific batch ingredient formulation to produce light reducing and / or heat absorbing glass products.

Total Heat Gain/Summer/Daytime – (BTU per hour, per square foot) The sum of the radiant energy and the conductive energy transmitted into the building. (Shading coefficient times ASHRAE solar heat gain factors + summer U-value times the indoor / outdoor temperature differences.)

Total Heat Gain/Summer/Nighttime – (BTU per hour, per square foot) The conductive energy transmitted into the building. (Summer U-value times the indoor / outdoor temperature difference.)

Total Heat Loss/Winter/Daytime – (BTU per hour, per square foot) The resultant of the radiant energy transmitted into the building and the conductive energy transmitted out of the building. (Shading coefficient times ASHRAE solar heat gain factors + the winter U-value times the outdoor / indoor temperature difference.)

Total Heat Loss/Winter/Nighttime – (BTU per hour, per square foot) The conductive energy transmitted to the outdoors. (Winter

U-value times the outdoor / indoor temperature difference.)

Transmittance – the fraction of radiant energy that passes through a given material.

Triple Glazing, Triple-pane Glass – Using three panes of glass in a window, separated by two gas spaces (usually Argon or Krypton) to increase energy efficiency and provide other performance benefits.

U-factor – The heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. A measure of the rate of non-solar heat loss or gain through a material or assembly. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value. Also known as *U-value*.

U-factor (total) – The area-weighted average thermal transmittance of a complete window, including center-of-glass, edge-of-glass, and frame U-factors.

Ultra-violet – Type of radiation with wavelengths shorter than those of visible light and longer than those of x-rays.

United Inches – Total of one width and one length in inches.

Units – Term used to refer to sealed insulating glass units.

U-value – The amount of conductive heat energy (BTUs) transferred through a one square foot area of a specific insulating glass unit for each one degree Fahrenheit temperature difference between the indoor and outdoor air. It is the inverse of the R value; U=1/R.

Visible Light – The portion of the electromagnetic spectrum that produces light that can be seen. Wavelengths range from 380 to 720 nanometers.

Visible Light Transmittance – The percentage of light in the visible spectrum range of 390 to 700 nanometers that is directly transmitted through the glass product.

Visible Transmittance (VT) – The fraction of visible radiation transmitted by a glazing system between the limits of 380 and 770 nanometers (0.38–0.77 micrometers). It is weighted according to the photopic response of the human eye (V-lamdba curve) and is expressed as a number between 0 and 1. Also known as *visible light transmittance (VLT).*

Warm Edge – Term used to describe technology that uses insulating spacers to achieve better thermal performance of an insulating glass unit, particularly evident in the increase of edge surface temperatures on the indoor side in the winter.

Weep Holes – Slots or holes in the sill (bottom) member of the sash frame to provide outdoor release of infiltrated water.

Wind Load – Pressure on a glass due to the speed and direction of the wind.

Wired Glass – Glass having a layer of meshed wire completely embedded in the glass lite. It may have polished or patterned surfaces.

REFERENCE SOURCES:

- ✓ ASTM Standard Spec. C1036-85
- ✓ ASTM Standard Spec. E1048-85
- ✓ ASTM Test Method E 546-83
- ✓ IGMA Glazing Manual
- ✓ IGMA North American Glazing Guidelines for Sealed Insulating Glass Units for Commercial and Residential Use
- ✓ SIGMA Guidelines for Sloped Glazing
- ✓ SIGMA Guidelines for Vertical Glazing
- ✓ Window Systems for High-Performance Buildings
- ✓ Various glass manufacturers' promotional literature

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GAS-FILLED IG UNITS – INCREASED INSULATION

As the demand for energy efficient products increases, interest is being shown in another way of improving the thermal and sound properties of Insulating Glass Units. By replacing the units dry air atmosphere with other dry gaseous atmospheres, both thermal "U" values and STC sound values are improved.

Low-emissivity coated glasses have been the exciting new product of the 80s. Will "gas filling" be the IG Unit major improvement of the 90s?

Why Gas Filling?

While gas filling has been used by PPG and LOF in their "glass edge" insulating glass units for over 20 years, it is a relatively new concept now being considered by insulating glass unit manufacturers in the United States using organic sealants in their units. Gas filling has been used with much success in Europe since 1972 due to their high cost of oil (up to six times higher than in the U.S.) which has made the Europeans even more energy conscious than Americans. Because of these circumstances, the European market traditionally has been the pioneer in the development of IG energy conversation techniques. Low-emissivity glass, for example, was widely used in Europe before becoming popular in this country.

In Europe, Germany has been one of the leaders in determining gas-filling standards. These standards, which have been incorporated into the German DIN testing standards, are used in many other countries as a model especially for quality control for gas-filled IG units.

Although gas filling is considered a relatively new practice, it first was developed in 1935 when patents were issued for gas filling recognizing the validity of the heat conductivity values of the different gases. In 1957, A. Krings and J.T. Olink published a paper about gas-filled IG units including some basic information on heat conduction measurement.

In the '60s companies started to develop machines for the industrial use of gas filling. Some of them had previous experience with medical applications of gas, and then applied this knowledge to the glass industry.

Since the mid '70s, the use of gas filling has grown in Europe. The bulk of the continental European market is represented by Austria, Belgium, Denmark, Germany, the Netherlands, Norway and Switzerland with a combined production of about 260 million square feet of gas-filled insulating glass units.

With the demand for energy efficiency increasing to North America, gas filling development is beginning to become a recognized way to achieve higher window thermal performance.

The Advantages

Gas filling is used to improve heat and/or sound insulation. The most commonly used gases are argon and sulfur hexafluoride (SF6). For maximizing thermal insulation, gas filling usually is combined with low-emissivity glasses.

By replacing the air in the unit's enclosed space with gas, the IG unit has an improved U-value by lowering its heat conductance characteristics, or any improved sound insulation by reducing the sound velocity.

TABLE 1
Double-Glazed IG Units
Two Lites Uncoated Glass

Glass Spacing	1/4" (6mm)		3/8" (10 mm)		1/2" (13 mm)		5/8" (16 mm)	
	U	R	U	R	U	R	U	R
Air Fill	0.66	1.52 (1)	0.61	1.64 (1)	0.60	1.67 (2)	0.57	1.75 (3)
Gas Fill	0.55	1.82 (1)	0.54	1.85 (1)	0.53	1.89 (2)	0.52	1.92 (1)
Improvement	17%	20%	11%	12%	12%	13%	9%	10%

Data Sources:
(1) Forschunginstitut fuer Waermeschutz, Munich (1978)
(2) Architectural Testing, York (1982)
(3) Glaeser (1977)
Test Unit size: 31.5" x 31.5"
Gas mix percentages, Argon/SF6 as follows:
1/4" space = 10 to 90, 3/8" space = 30 to 70, 1/2" space = 80 to 20

Thermal Improvements

Energy transfer through an insulating glass unit takes place three different ways: conduction, convection and radiation.

Heat loss by conduction occurs because heat always flows toward cooler temperatures. Gas, being more dense than air, slows the flow of building heat to the outside in winter and reduces the outdoor heat that can enter in the summer. Convection is heat transfer caused by gas movement in the space between the glass lites. This is largely an effect of the specific gas type and unit enclosed space. Radiation heat transfer through the units is normally not affected by gas filling. However, SF6 has some effects on radiation due to its absorption of certain wavelengths of infrared radiation.

Table 2
Triple-Glazed IG Units
Three Lites Uncoated Glass

Glass Spacing	1/4" (6mm)		5/16" (8 mm)	
	U	R	U	R
Air Fill	0.48	2.08	0.46	2.17
Gas Fill	0.36	2.78	0.37	2.70
Improvement	25%	33% (1)	20%	24% (2)

Data Sources:
(1) Forschungingstitut fuer Waermeschutz, Munich (1978)
(2) Architectural Testing, York (1982)
Test Unit size: 31.5" x 31.5"
Gas mix percentages, Argon/SF6 as follows:
1/4" space = 10 to 90, 5/16" space = 80 to 20

TABLE 3
Double-Glazed IG Units
One Lite Pyrolytic Low E (E=0.30)
One Lite Uncoated Glass

Glass Spacing	1/4" (6mm)		3/8" (10 mm)		1/2" (13 mm)		5/8" (16 mm)	
	U	R	U	R	U	R	U	R
Air Fill	0.52	1.92	0.45	2.22	0.40	2.50	0.37	2.70
Gas Fill	0.45	2.22	0.39	2.56	0.35	2.86	0.34	2.94
Improvement	13%	16%	13%	15%	13%	14%	8%	9%

Date Sources:
Glaverbal, Brussels (1988)
Test Unit size: 31.5" x 31.5"

Gas filling reduces heat loss (U-value) of a ½" airspace uncoated glass unit filled with argon by about 12 percent (Table 1) and by 13 – 18 percent (Tables 3, 4, 5) for the already thermally improved low-emissivity glass units. Gas filling for thermal insulating is usually argon gas combined with low-emissivity glasses for maximum effectiveness.

The gases used improve the thermal behavior of IG units because they have a lower heat conductance (transfer of heat toward the cooler temperature side of the glass) value than air. The thermal performance benefits are illustrated in Tables 1-7.

Since these gases are heavier than air, there is less gas movement (convection) than with a simple air space unit. The wider the space between the two lites of glass in an IG unit, the more convection that can occur. So gas filling, particularly with uncoated glass units, is more effective with narrow interspaces with the percentage gain decreasing with wider interspaces. Low-emissivity and solar reflective coated glasses produce cooler inner spaces and therefore less gas movement.

Tables 1-6 illustrate this point: the higher the emissivity value of the glass, the greater the improvement in U-value compared to an uncoated glass unit when the interspace widens.

As shown, uncoated glass units with an enclosed space of ½" of gas are less effective than the low-emissivity glass units. Gas filling provides good user benefit for spaces up to 5/8". The 5/8" data shows the beginning of the lower percentage improvement with wider glass spaced units.

TABLE 4
Double-Glazed IG Units
One Lite Pyrolytic Low e (E=0.15)
One Lite Uncoated Glass

Glass Spacing	1/4" (6mm)		3/8" (10 mm)		1/2" (13 mm)		5/8" (16 mm)	
	U	R	U	R	U	R	U	R
Air Fill	0.46	2.16	0.37	2.70	0.34	2.96	0.30	3.32
Gas Fill	0.39	2.57	0.31	3.23	0.28	3.52	0.26	3.81
Improvement	15%	19%	16%	19%	18%	19%	13%	15%

Data Sources:
Glaverbel, Brussels (1988)
Test Unit size: 31.5" x 31.5"

TABLE 5
Double-Glazed IG Units
Two Lites Uncoated Glass

Glass Spacing	1/4" (6mm)		3/8" (10 mm)		1/2" (13 mm)		5/8" (16 mm)	
	U	R	U	R	U	R	U	R
Air Fill	0.48	2.08	0.35	2.87	0.29	3.45	0.26	3.85
Gas Fill	0.36	2.78	0.25	3.52	0.24	4.17	0.22	4.55
Improvement	25%	33% (1)	20%	23% (2)	17%	21% (1)	15%	18% (1)

Data Sources:
(1) ETC Laboratories (1985)
(2) Glaverbel (1988) – calculated interpolation
Test Unit size: 36" x 48"

Gas filling has been effectively used in both commercial and residential markets. Additional benefits have resulted when using argon in low-emissivity solar reflective units as shown in Table 7. Depending upon the percentage of the glass area to that of the total building, the savings in heating system installation costs and operation costs may be reduced substantially compared to normal glazing procedure.

Gas filling improves thermal behavior of IG units because gases have a lower heat conductance value. The heat conductance represents approximately 30 percent of the total energy transmission through an IG unit, another 30 percent occur through convection and the last 40 percent through radiation.

Sound Absorption

Due to increased legislation (such as the California Sate Sound Protection Codes which prescribe sound control for windows in noisy areas), sound absorption glazing is fast becoming a hot issue.

A gas-filled unit is more efficient at noise reduction because the gas mixtures reduce the sound pressure and react in such a way as to maximize sound absorption.

TABLE 6
Triple-Glazed IG Units
Two Lites Vacuum
Coat Low-E (E=0.09)
One Lite Uncoated Glass

Glass Spacing	1/2" (13 mm)	
	U	R
Air Fill	0.19	5.3
Gas Fill	0.13	7.7
Improvement	32%	46%

Data Sources:
Loewen Windows (1988)

Depending upon the glass thickness, a gas-filled IG unit can reduce sound by 3 – 4 decibels. Because it is a heavy gas (almost five times the density of air), SP6 gives the best results for sound insulated units. A double-glazed unit filled with SF6 compared to the same unit construction with air fill can improve the sound absorption by up to 8 decibels. However, SF6 is relatively expensive and will increase the cost of the unit. SF6 is normally used in smaller airspaces since increased convection in larger airspaces could offset some of the advantage of lower thermal conductivity of the gas.

Durability

Gas filling is effective in increasing thermal and sound control but will it last? The news is good – there is no gas loss in the “glass edge” units, and the reports on the European “organically sealed” units are that users can expect a long service life.

The accepted DIN Standard is a test assuring a unit does not lose more than 1 percent of the gas per year. On this basis, the unit would not lose any efficiency for 15 years as an 85 percent gas fill is considered still highly effective. Most units tested, however, have better gas retention than required by the DIN Standard.

Conclusion

Gas filling is quickly becoming the new rage in IG units and with good reason with its proven track record of the “glass edge” units of the United States and the “organically sealed” units of Europe. Argon gas can substantially improve U-values. SF6 gas provides significantly lower sound transmission. Combinations of both gases present an opportunity to obtain improvements in both thermal and sound characteristics of an insulated glass unit.

TABLE 7
Double-Glazed IG Units
One Lite High
Performance Reflective Plus
One Lite Uncoated Glass

Glass Spacing	1/2" (13 mm)	
	U	R
Air Fill	0.3	3.3
Gas Fill	0.24	4.2
Improvement	20%	27%

Data Sources:
Interpane Coatings (1986)

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