NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB49-17 (2022)**

Performance Improvements in Insulating Glass Units: Cavity Gap and Insulating Gases

Introduction of Properties

The Insulating Glass Unit (IGU) has been a staple of construction for many years, replacing single lites of glass in all but a few areas. The basic principle of an IGU is improving thermal performance by incorporating a gap between two or more lites of glass. A properly sized gap will reduce convection within the IGU with no effect on daylighting, thus reducing thermal transfer by as much as half. The design professional can further improve thermal performance by choosing from a variety of IGU component options such as coated glass products with low emissivity properties, insulating gases, multi-cavity IGUs and varying cavity gap width. The most common insulating gas used is argon. Other more exotic gases are typically utilized in more complex constructions for greater thermal performance improvement

Importance of Gas Content

When the design professional chooses to use a gas other than air, it is understood that the thermal performance improvements of the IGU are dependent on the ability of the IGU to retain the insulating gas. A reduction in the concentration of insulating gas within the IGU has a linear correlation to the reduction in the thermal improvement of the unit. Gas retention within an IGU is dependent on several variables including, but not limited to:

- Permeability of the sealants used in the edge seal construction
- Permeability of the spacer
- Integrity of the bond between glass and sealants, and spacer and sealants
- Sealant bond width
- Uniformity of the sealants used in the unit construction
- Cleanliness of the glass and spacer during construction of the IGU that enables proper adhesion of sealants
- Fluctuation of internal airspace pressure due to wind loads, changes in temperature, altitude, glazing system, and general environmental conditions

Testing and Certification

ASTM E2190 *Standard Specification for Insulating Glass Unit Performance and Evaluation* references established methods to evaluate gas content before and after a laboratory accelerated weathering process.

This is a laboratory testing specification for a standardized size and construction of IGU (14” x 20”) and cannot be used to evaluate any IGU that has been installed in a window or glazing system. Under ASTM E2190, gas concentration is measured before and after weathering testing of IGUs typically through the use of Spark Emission Spectroscopy (SES).

While laboratory testing represents the performance of a given set of test specimens, it does not necessarily validate the performance of production units that are installed in a given window or a glazing system. A successful test denotes that the edge seal design and workmanship of the specific units tested passed the requirements of the standard.

Product certification is a third-party, independently audited program that requires the regular inspection of product manufacturing facilities to ensure that the IGUs being manufactured are representative of the products that were tested to ASTM E2190. Additionally, it ensures that manufacturing and quality control processes are in place with the intent of consistently producing the product. Utilizing an industry recognized, independent third-party certification program provides a greater level of confidence in the longevity of the thermal performance of an IGU. Product certification includes marking and traceability of products to the IGU fabricator.

Product Ratings

Historically, IGU thermal performance charts provide only center-of glass performance numbers. However, total fenestration system thermal performance and condensation resistance is based on the edge of glass, the center-of-glass, and the frame thermal performance values. It is important to understand that there is a difference between center-of-glass value versus total system values.

While center-of-glass U-factors are useful for comparison in many glass products, the center-of-glass U-factors will typically be lower than the total fenestration system U-factors.

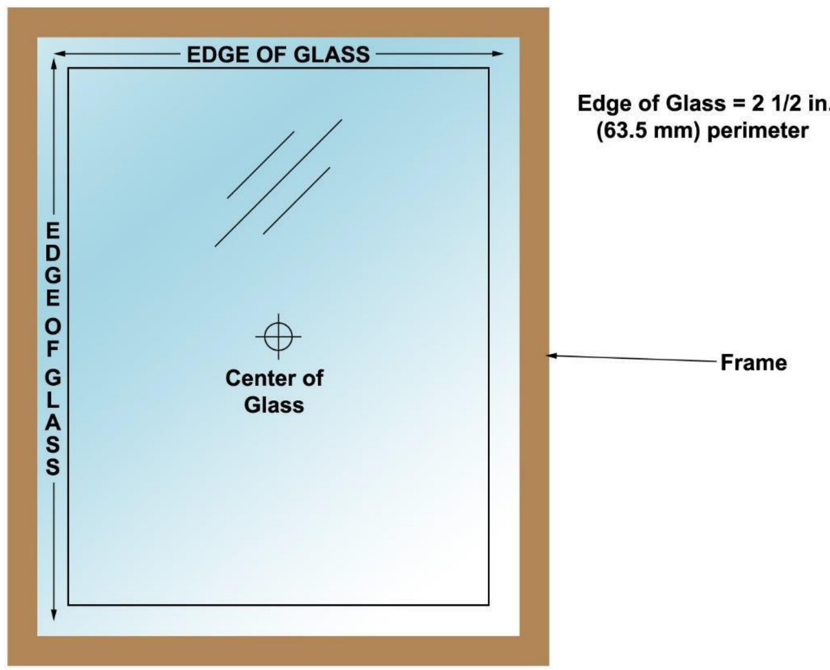

__Figure 1:__ Components of Total Fenestration U-factor (Center-of-Glass, Edge of Glass and Frame)

The fenestration industry measures the thermal performance of its products in terms of thermal transmission, or U-factor (also known as U-value), which is expressed in Btu/hr/ft^2/°F. U-factor is a measure of the air-to air heat transmission (loss or gain) due to the thermal transmittance resulting from the difference between indoor and outdoor temperatures. As the center-of-glass U-factor decreases, so does the amount of heat that is transferred through the IGU. The lower the U-factor, the better the product will insulate a building.

U-factor and R-value are reciprocals. For instance, dividing 1 by the U-factor will obtain the R-value for glass (Example: a 0.25 U-factor equals an R-value of 1/0.25, or 4). However, U-factors and R-values for other building materials (ex. insulation) are not always directly comparable to glass.

Insulating Gases

Some inert gases are less thermally-conductive than air and thus will lower (or improve) the U-factor of the IGU, typically in the range of 10 to 15 percent. The inert gas most commonly used between the lites of a low-E IGU to improve its thermal performance is argon, although krypton and argon-krypton mixtures have seen increased use in recent years.

Optimize the Cavity Gap

A key to proper IGU design for insulating gases is to optimize the cavity gap for the gas being used. There is an optimal spacer width for every type of low conductivity gas which minimizes the gas convective heat transfer (see Figure 2). This optimum gap width differs for different gas types and different weather conditions. In general, warmer weather conditions result in wider optimum gap widths. The free LBNL *WINDOW* computer program can be used to readily determine optimum gap widths for unique conditions. In North America, the NFRC standard summer or winter environmental conditions are used in the calculation. Consult the fabricator for cavity gaps available, as spacers are only available in discrete dimensions.

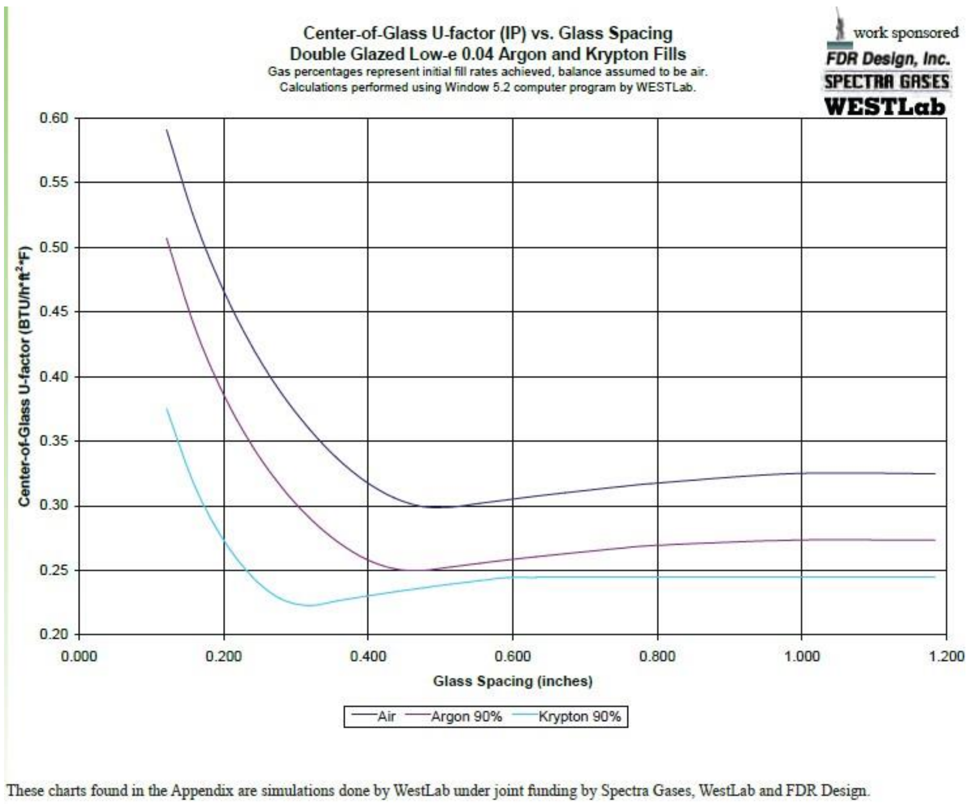

Figure 2: *Center of Glass U-factor as a function of gap thickness and gas content*

As noted in Figure 2, different gases have different optimal glazing space gaps based on their respective densities to reduce convection inside the IGU, while also having the greatest possible distance to reduce conduction.

The typical nominal gap width dimension are:

- for air, approximately 1/2 inch (13mm)
- for argon, approximately 7/16 inch (11-12 mm)
- for krypton, approximately 5/16 inch (8 mm)

Anything greater will increase convection inside the IGU, decreasing thermal performance. For additional information, please contact the IGU fabricator.

The chart below depicts the interior surface temperature of glass and U-factor based on the various glass constructions shown using NFRC 100 calculations at standard conditions of 0 degrees F and 70 degrees F interior and 12.3 mph windspeed. Values depicted are based on center-of-glass temperatures.

A comparison of single to dual to triple configurations with different gaps and gases is as follows:

	U-Factor (Btu/hr/ft^2/°F)	**Interior Center of Glass Surface Temperature (°F) with an outside temperature of 0°F**	**Overall glazing width**
Monolithic (Single) Glazed (¼")	1.02	16	¼"
Double Glazed/LowE (#2) Air (¼" – ½" – ¼")	0.29	54	1"
Double Glazed/LowE (#2) 95% Argon (¼" – ½" – ¼")	0.24	56	1"
Double Glazed/LowE (#2) 95% Krypton (¼" – ½" – ¼")	0.23	57	1"
Triple Glazed/LowE (#2) Air (¼" – ½" – ¼" – ½" – ¼")	0.22	58	1.75"
Triple Glazed/LowE (#2) 95% Argon (¼" – ½" – ¼" – ½" – ¼")	0.18	59	1.75"
Triple Glazed/LowE (#2) 95% Krypton (¼" – ½" – ¼" – ½" – ¼")	0.17	60	1.75"
Triple Glazed/two LowE (#2, #5) 95% Argon (¼" – ½" – ¼" – ½" – ¼")	0.12	63	1.75"
Triple Glazed/LowE (#2) 95% Argon (¼" – 3/8" – ¼" – 3/8" – ¼")	0.20	59	1.5"
Triple Glazed/LowE (#2) 95% Krypton (¼" – 3/8" – ¼" – 3/8" – ¼")	0.16	60	1.5"
Triple Glazed/LowE (#2) 95% Argon (3/16" – 3/8" – 1/8" – 3/8" – 3/16")	0.20	58	1.25"
Triple Glazed/LowE (#2) 95% Krypton (3/16" – 3/8" – 1/8" – 3/8" – 3/16")	0.16	60	1.25"
Triple Glazed/two LowE (#2, #5) 95% Krypton (3/16" – 3/8" – 1/8" – 3/8" – 3/16")	0.10	64	1.25"
Calculated in accordance with NFRC 100. Where low-e coating is indicated, emissivity = 0.04 is assumed, and surface location is indicated.			

These are representative of typical IGU constructions, showing the effect of inert gas, gap distance, and low-e coating. See fabricator for actual performance of specific glass constructions and gas mixtures.

The cavity gap size and addition of gas or coatings should be selected based on the performance requirements of the building envelope. As demonstrated in the table, inert gases (argon, krypton) offer lower U-factor than with air, but also, the effect of using krypton gas in place of argon gas is more beneficial with narrower gaps than with wider gaps. The use of multiple low-e coatings can also significantly reduce U-factor. The interrelated nature of properties like U-factor and building interior glass surface temperature means that at times performance in one aspect may need to be reduced to achieve better performance in another. In addition, choice of overall IG thickness may be a consideration based on the framing system, which can then affect gap distance, glass thickness, and choice of inert gas. A detailed explanation of this topic is outside the scope of this document. Consult the product fabricator to determine which products are needed to satisfy the required building needs.

This Paper was developed by dedicated member volunteers and subject matter experts. The original version of this document was approved and published in 2016. This version of the Paper was updated and published in July 2022.