Glass Technical Paper FB66-20

Introduction to Vacuum Insulating Glazing

Vacuum Insulating Glass (VIG) provides similar or superior thermal performance to conventional double glazing in the thickness of a single glass lite. The gas in the space between two lites of glass is extracted to create a vacuum, rather than filled with air or argon. The thin profile can be installed in new construction, restoration projects and refrigeration applications.

VIG is comprised of two glass lites, typically 0.12 in. to 0.23 in. (3 mm to 6 mm) thick that are hermetically sealed around the edges. The air between the two lites is extracted, either through a small pump-out tube (also known as an evacuation port) or by using a vacuum chamber. The glass lites remain separated by pillars (also called microspacers) approximately 0.005 in. to 0.012 in. (0.15 mm to 0.30 mm) thick. The pillars are made of high strength material such as metal or ceramic and may be arranged in various patterns across the surface of the glass. Examples of patterns are a uniform grid or in a pattern spaced wider in the center of the array and closer together toward the edges. The pillars may be glued in place or held in place by the glass. Once a vacuum is made, the edges (and the pump-out tube if applicable) are sealed to create a permanent vacuum. For units that have a visible pump-out tube, there may be a safety cap placed over the tube for additional durability. Some VIG units may include a getter; a component in the VIG that continually removes residual outgas molecules to help maintain vacuum over time. A getter may be a separate, visible component or incorporated in another component of the VIG, such as the edge seal.

The pressure of the evacuated cavity is typically on the order of 0.1 Pa to eliminate the conductive and convective heat exchange between the two lites of glass. To reduce radiative heat exchange, a low-e coating can be used on one of the internal surfaces of the VIG, typically surface 2.

Matching flatness on both lites of glass is critical to successful VIG fabrication to keep the array of pillars in place. Keeping the pillars in place prevents the lites from touching to avoid creating a thermal conduction pathway that could reduce the performance of the VIG.

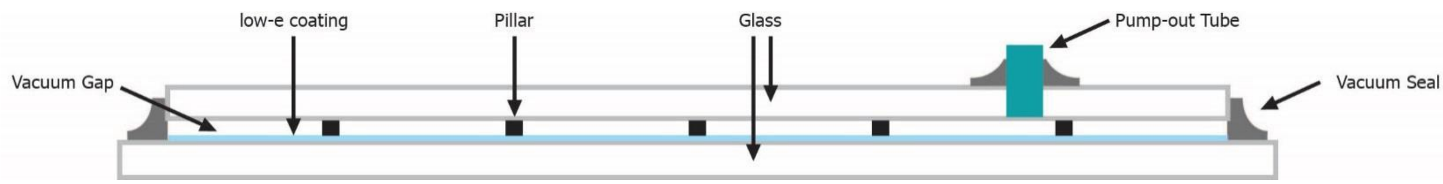

Figure 1: Diagram of a typical VIG unit

Current VIG Market Application

<u>New Construction</u>

VIG can be installed as a monolithic lite or as part of an IGU. Hybrid VIG can be used to further reduce U-factor and SHGC. In a hybrid VIG unit, one of the lites of a standard double glazed IGU with air or gas-filled space is replaced with a VIG. Laminated VIG can be used to improve sound control, add protection against impact from wind-borne debris or forced entry, and comply with the requirements of safety glazing. In a laminated VIG unit, one of the lites of a standard double glazed laminate is replaced with a VIG. In these constructions, the lite added to the VIG may be heat-treated, have a low-e coating, or have other properties that improve the thermal or acoustic performance. Double or triple insulated units using VIG to replace individual glass lites is also possible for future development.

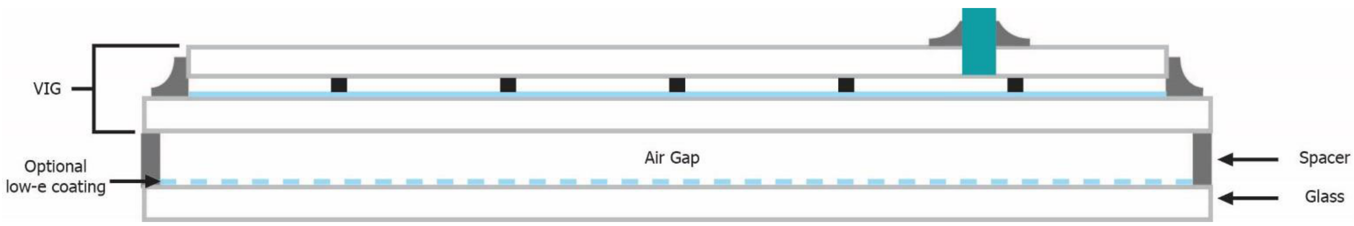

Figure 2: Diagram of a typical Hybrid VIG unit

Figure 3: Diagram of a typical laminated VIG unit

New construction design with VIG offers two distinct benefits compared to traditional glazing:

- Frame/sash design or weight design: VIG offers higher energy performance in a significantly thinner profile than typical IGU construction. This benefit allows window and sash designs that are much thinner or lighter weight than typical construction methods using IGUs. The key benefits of a thinner profile product include wall thickness, window thickness, matching existing window extrusion design, or to reduce overall glazing component weight.
- Higher performance for given profile – By utilizing the VIG either as a standalone product or in a hybrid VIG, manufacturers can exceed the performance values of typical IGU design required by model building codes. VIG can enable compliance with more stringent energy standards such as Passive House, Local Law 97, etc.

Restoration

The thin profile of VIG allows buildings designed for the weight of monolithic glass to achieve and/or exceed the thermal performance of double glazed or triple glazed units. VIG can be used in an existing sash to reduce installation costs and maintain historic integrity. VIG may also be used as an interior storm lite for additional performance.

Refrigeration

Refrigeration applications typically require both low condensation potential and high insulation values. VIG offers significant benefits for the refrigeration market compared to traditional IGU construction, such as slim profile, energy efficiency and high visibility for consumers to see and access products.

Safety requirements in commercial refrigeration can be met with tempering, lamination, or film, similar to architectural safety glass.

Energy Performance

Key drivers for energy performance include pillar array, vacuum level and the addition of low-e or other solar coatings.

- Pillar array– The pillar array affects convection and conduction components of heat transfer. The distance between pillars can be increased if thicker glass or heat-treated glass is used. A wider pillar array allows for less heat transfer, so a lower (better) U-factor can be achieved. However, a wider array must not allow the two lites to touch which may cause unacceptable glass distortion and be aesthetically unappealing.
- Glass coating – The emissivity of the glass coating, along with the placement and number of coatings used drives the energy performance as well. A higher performing low-e can reduce both the SHGC and the U-factor, as they would in a standard IGU.
- Vacuum level – Lower pressure reduces heat flow.

Acoustic Performance

Sound waves do not travel through a vacuum, so the VIG design may offer improvements in acoustic performance and a reduction in sound transmission. In general, VIG offers improved sound reduction performance when compared to a single lite with the same thickness as the VIG unit. VIG can be combined with lamination, acoustic PVB, and hybrid IGU design to further improve sound attenuation. Refer to VIG fabricator for product specific acoustic performance.

Standard Available Capabilities

VIG design and availability vary significantly by manufacturer and market. Consult with VIG manufacturers by application and project destination for availability and size limitations.

- Typical sizes
  - Minimum - ~5 x 14 in (125 x 350mm)
  - Maximum - ~ 59 x 94 in (1500 x 2400mm)
  - Limited designs may be available in larger sizes. Contact the fabricator for details.
- Thicknesses
  - Typically range from 0.25 to 0.5 in (6 – 12 mm) for monolithic design VIG
  - Thicker for laminated or hybrid construction

Because VIGs are hermetically sealed with a low vacuum pressure, the shipping and installation altitudes compared to manufacturing location are negligible. As such, VIG can be air freight shipped or installed in high altitude locations without issue. Hybrid VIG/IGU units must be treated the same as standard IGU glazing.

- Form Limitations:
  - Shape -- Non-rectangular shapes can be made by some manufacturers, but the size limitations typically are driven by the more difficult manufacturing methods. In most cases, there are larger minimum sizes required, at least two 90° corners are needed, and shapes are limited to fairly simple parallelograms or simple arcs.
  - Bent – Not currently possible.

VIG Testing and Test Standards

ISO standard 19916-1:2018: *Glass in building- Vacuum insulating glass- Part 1: Basic specification of products and evaluation methods for thermal and sound insulating performance* specifies evaluation methods for thermal and sound insulating performance and test methods for thermal insulation durability. Development of parts 2-4 of the ISO standard are currently in progress to standardize other test methods.

The National Fenestration Ratings Council (NFRC) is developing a procedure to determine VIG center-of-glass and overall window U-values and to validate modeling procedure in Lawrence Berkeley National Lab (LBNL) WINDOW and THERM software in accordance with NFRC 100.

Because VIG units are sealed with a hermetic, often inorganic material, it is possible that the edge seals may have a longer life cycle as there is no organic material to break down over time. The expected longevity of VIG units cannot be predicted until the technology is more widely adopted in the market.

Terminology

Getter: an optional component in the VIG that continually removes residual outgas molecules as produced to help maintain vacuum over time

Hermetically sealed: airtight seal that will keep moisture and other gases from penetrating the sealed unit

Hybrid VIG: a standard double glazed IGU with air or gas-filled space combined with VIG

Insulating Glass: two or more lites of glass separated by spacer material(s) incorporating a drying agent (desiccant) and hermetically sealed around the perimeter with one or more sealants.

Laminated Glass: an assembly of two or more lites of glass bonded together with an interlayer material

Laminated VIG: a standard VIG unit bonded with an interlayer to an additional glass lite

Low-e coating: Low emissivity coatings are used to limit the radiant heat energy that pass through the glass. A thin coating on the surface of the glass is used to reflect infrared light or heat energy while still letting visible light through the glass. Different coatings will be used in different climates to get the desired effect.

Pillars: spacers approximately 0.005 in. – 0.012 in. (0.15 mm to 0.30 mm) thick made of high strength material such as metal or ceramic, used to separate the two lites of glass in VIG. The spacers can either be glued in place or held in place by the glass.

Pillar array: the arrangement of microspacers in VIG. Spacers can be arranged evenly across the surface of the glass, or in any pattern.

Pump-out tube: also referred to as vacuum port, evacuation port, evacuation tube. A port in the VIG assembly through which air between the two lites of glass is extracted.

Radiative heat exchange: Radiation is the energy that is transmitted through space in the form of waves or particles. All objects radiate heat in the form of short or longwave radiation. The hotter the object, the shorter wavelength radiation.

The sun is the major form of short-wave radiation. The long wave radiation comes from other objects in the surroundings.

SHGC: Ratio of the solar heat gain entering the space area through the fenestration product to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted or convected into the interior.

Surface 2: An example of Glass Surface Orientation / Designation: the numerical identification of a specific glass surface relative to the exterior surface of the assembly. The first surface is the exterior surface with each consecutive glass surface identified in order from exterior to interior with the last (highest number) surface being on the interior of the assembly.

U-factor: Measures the air to air heat transmission due to the difference in indoor and outdoor temperatures and incident radiation. This measurement accounts for all three modes of heat transfer. The lower the U-factor (U-value) the less heat that can transfer through the IG. R values can be used instead of U value; R value is the inverse of the U value. The higher the R value, the more thermally insulating the IG is.

References

McSporran, N. "Properties and Performance of Vacuum Insulated Glazing" Journal of Green Building

ISO 19916-1:2018: *Glass in building- Vacuum insulating glass- Part 1: Basic specification of products and evaluation methods for thermal and sound insulating performance*

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