

A CLEAR ADVANTAGE: Evaluation Criteria for Visual/Performance Qualities of Fire-Rated Glass Ceramics

A new generation of glass ceramic materials that provide fire-protective assemblies for fire-rated separations can be specified for multifunctional performance. Qualitative and quantitative evaluation criteria are useful for architects and building design teams.

ABSTRACT

New glass ceramics technology presents advantages for aesthetics and architectural performance, opening a new chapter in fire-rated glass assemblies that blend in seamlessly with building design. Architects, facility managers and glazing contractors use specific evaluative criteria to select glass ceramic materials with desirable visual and aesthetic properties.



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INTRODUCTION

Fire-rated glass and glazing assemblies deliver safety and security benefits while offering a number of aesthetic and functional qualities that building teams demand from architectural glass. These systems include fire-protective and fire-resistive glass formulations (see sidebar on this page). While the two are different, they are both able to meet and exceed building codes and life-safety requirements, according to a number of code experts and authorities having jurisdiction (AHJs). In addition, these products allow the opening up of fire separations and exterior walls, which benefits building occupants and helps meet sustainability goals.

However there have been longstanding limitations of fire-resistant glass ceramics from an aesthetic standpoint. In addition, there are well-known shortcomings in performance that have limited the acceptance and application of architectural fire glazing. In particular, glass ceramics offer excellent life-safety characteristics but until recently have been associated with undesirable visual, color and reflectivity attributes.

A novel glass ceramic technology has been introduced that addresses these drawbacks, expanding the ability of a fire-rated glass ceramic to meet the multifunctional requirements demanded for today's high-performance building projects. This innovative glass ceramic formulation¹ is presented in this technical brief, with a discussion of its tested performance values and benefits in architectural applications.

The glass ceramic technology is shown to improve on standard architectural fire-rated glazings in a number of notable and beneficial ways. In particular, it allows closer matching of visual qualities of standard float glass. The new glass ceramics also provide improved performance for a number of functional attributes.

For architects, specifiers, façade consultants and other building design professionals, this breakthrough offers an opportunity to select ceramic glazings based on a broad range of functional requirements. These include visual properties such as distortion, UV absorption, and light transmission as well as measurable aesthetic values, such as color rendering, reflectivity, clarity and transmitted light quality.

EXPECTATIONS FOR ARCHITECTURAL GLAZING

Defining the key visual and performance criteria for architectural glass ceramics allows for a close analysis of the materials' capabilities. Among the primary multifunctional challenges is matching the visual qualities of standard float glass with adjacent or nearby fire-rated glass on the same assembly, façade or separation. This includes the historically difficult task of matching float glass with glass ceramics.

In particular, the desirable qualities of architectural glass—and architectural fire glazing—include effective levels of sound transmission reduction, ultraviolet (UV) absorption, energy performance, and light transmission.

In addition, glass is measured and specified for adequate function with respect to color, reflectivity, surface quality, clarity and shadow. The products must also meet all codes and relevant standards

About Fire-Rated Glazings

Fire-protective glass including glass ceramic is designed to compartmentalize building sections and block smoke and flames, but not the transfer of heat to the opposite side of the glass. Fire ratings range from 20 to 180 minutes. There are limitations as to where in the building it can be used and to its maximum area (typically $\leq 25\%$ of the wall).

Fire-resistive glass is made with two or more layers of safety glass with an intumescent interlayer or gel, providing insulating layer(s) to not only block smoke and flames but also provide a barrier to heat. The glass conforms to ASTM E-119 (Fire Tests of Building Construction Materials) non-load-bearing-wall test requirements and does not face area limitations due to its heat insulation characteristics. Fire-resistive glazing is employed to prevent the spread of fire through conduction, convection or radiation (heat transfer). This helps reduce the risk of burns and also impeded egress that can occur due to the sensation of heat experienced by building occupants.

Source: Vetrotech/Saint-Gobain

governing the minimum impact performance of the materials and assemblies, including ASTM and ANSI testing protocols.

However there are well-documented limitations of fire-resistant glass from an aesthetic standpoint and performance criteria beyond fire performance that have constrained the application of glass ceramics. In general, glass ceramics comprise a crystalline phase and a residual glassy phase, and have a linear expansion coefficient of close to zero² giving glass ceramics the unique characteristic of not breaking from thermal stress, even in extreme exposures (i.e. cold water on glowing red cook top); in addition to architectural fire-rated applications, they are used for stove and range tops. However they are known for higher levels of distortion and haze as well as difficulty in controlling color, tint, or controlling color of objects viewed through glass ceramics. In some cases, general workability and compatibility with framing materials and sealants has been a concern. As mentioned, the new technology for glass ceramics improves the ability of the glazings to meet desired levels of performance. Using a novel chemical composition and processing technique, the glass ceramic is able to very closely resemble float glass, with matching capabilities unseen in previous formulations. In addition, special raw materials and a proprietary manufacturing process have been developed to ensure that the glass ceramic's physical and optical properties are engineered to be as close as possible to those of standard architectural float glass.

MULTIFUNCTIONAL GLAZING

As in other fields of application, architectural glazing demands, rather than a single performance level, a number of specific, complementary functional attributes. These traits have been defined and listed below with attention to typical architectural specification needs. Together these attributes are required or preferred for an effective multifunctional glazing design.

Core specification objectives for a building application include a clear view through glass of the correct color for the design intent. Other assumed issues include fire rating, sound reduction capacity (typically given as sound transmission coefficient, or STC of the glass panels and/or framed glass assembly) and energy-related values such as emissivity and U-values, visible light transmission (VLT), solar heat-gain coefficient (SHGC) and the ratio of VLT/SHGC, or the ability to selectively transmit visible light while blocking UV and infrared (IR) light.³

For architectural applications, an entire class of evaluation criteria is focused on visual and aesthetic performance variables. These measures should also be applied to fire-rated glass ceramics, which have traditionally had poor functional qualities in terms of appearance. Among the most critical factors for visual and aesthetic performance are:

Surface Quality

A measurable value defined as sharpness and brilliance, including the accurate and undistorted definition of objects seen behind the glass. Standards covering this include ASTM C1036-11, the Standard Specification for flat glass, describes surface quality standards for flat glass. Other standards specifically cover heat-treated flat glass (ASTM C1048) and laminated architectural flat glass (ASTM C1172).

Blurriness

Glass with even a slightly rough surface diffuses the transmitted light, results in partial light transmittance. Smooth glass surfaces provide for the sharpest display of objects viewed through the glass.

Haze or haziness

Haze describes how “cloudy” a view through one or more glass panels appears to be. Haze is mainly caused by inhomogeneity within the glass.

The degree of haze is given as a percentage (haze value in %) is determined per stringent standards in terms of light transmission or variance of refractive index distribution using a spectrophotometer.⁴ Haze values range from 0.5% for new-generation glass ceramics⁵, although most glass ceramics on the market have haze values ranging from 0.9% to 2.5%, which is a visually significant differential.

Color Rendering

The appearance of color through glass is measured with the color rendering index (CRI). Generally, the darker or more colored the glass tint, the higher the deviation from the actual color of areas or objects viewed through the glass. Color representation is determined using a CRI baseline (true color) of 100. The closer the CRI value (Ra) is to 100, the better or truer the color rendering. Standard clear float glass, for example, typically has a measured Ra of 98.8; low-iron glass is about 99.7.

Glass ceramics started out with much lower Ra values, although the newer fire-rated glass ceramic formulation discussed here has an exceptional CRI value of Ra 97.1 (see footnote 5).⁵ Experts in glass technology have confirmed that this value most closely compares to that of standard float glass.

² <http://www.yourglass.com/agc-glass-europe/be/en/home.html>

³ Better Bricks, “Which Glass Should I Use?”, <http://www.betterbricks.com/design-construction/which-glass-should-i-use>

⁴ Journal of the American Ceramic Society, “Glass Inhomogeneity Measurement ...” <http://onlinelibrary.wiley.com/doi/10.1111/j.1151-2916.1985.tb10147.x/abstract>

In addition, there are tradeoffs in clear glass ceramic technology, says glass industry expert Lindsay Hampton Varma with Vetrotech Saint-Gobain. “It is possible to reduce a certain amber hue of the glass ceramic for a more neutral color appearance,” she explains, citing extensive testing performed by her and other companies, including Schott. “However, the significant tradeoff is a higher haze value—presented as a gray appearance—and a reduced color rendering index.”

Visible Light Transmission.

As mentioned above, VLT describes the capacity of light to pass through a glass panel, and VLT is measured with a spectral photometer. The light transmission covers the wavelength of electromagnetic radiation between 380 and 780 nanometers.

Recent studies and user experience show that high VLT levels contribute to improved comfort for building occupants, because the greater VLT means greater levels of natural daylight within the building interior. In terms of subjective perception, visual acuity performance, scientific health benefits and subjective or qualitative measures such as comfort, higher VLT corresponds with healthier, more natural building interiors.

In addition, the higher the VLT measures, the higher the potential for use of daylighting to offset the use of electrical lighting. This is described by the following formula, showing that the higher the absorption and reflection of natural daylight by the glass matrix, the lower the light transmission⁶, as required by the law of conservation of energy:

$$\text{Transmission } (T) + \text{Absorption } (A) + \text{Reflection } (R) = 1$$

UV Transmission

A related measure is ultraviolet transmittance or transmission, which is the percentage of radiation that can pass through glazing. Electromagnetic radiation between 280 and 380 nm (UV transmittance) is visible to the human eye and can pass through architectural glass, so this part of the spectrum is the focus of glass testing.

Other parts of the spectrum, such as very shortwave UV light—UV-C range—is already filtered out by the earth’s atmosphere. Much of the middle UV range, or UV-B, is greatly reduced by typical glass materials. The long-wavelength UV-A portion, transmittance depends on the glass composition, and it is usually partially permeable⁷. Some types of glass, such as Keralite Select, fully absorb UV light and convert the transmittance completely

to harmless heat radiation. UV light is high-energy radiation and a known cause of skin cancer, and it damages solid organic substances and can lead to premature deterioration of interior finishes and furnishings and other building contents.

VISUAL AND AESTHETIC MEASURES

In addition, there are a number of aesthetic performance factors that must be considered in the use of fire-rated glazings.

Color and color shift

The measure of true color is an important visual performance characteristic for architectural glass selection. Depending on their coatings and tints, two glass panels may appear to have a different light transmission colors; some may have a pronounced hue, such as greenish, blue, or reddish purple. This effect can be quantified as specular reflectance, using a spherical reflectance apparatus backed with a light trap so that only specular reflectance is measured, according to the testing firm Hunter Lab.⁸ Coatings used in insulated glazing units (IGUs) with laminated glazing may appear to have a color different from the standalone glass panels. Opacifier coatings and interlayers can magnify this color shift.⁹ Matching the hues of glass ceramics with standard float glass is also challenging.

Reflectivity

Specular reflectance also helps quantify and describe the reflectivity of glass. Most glass has a reflectivity of nearly zero except at the corresponding reflected angle. Typical glass ceramics, however, can have a more diffuse reflectivity than normal float glass. New glass ceramics have better properties of specular reflection, so they can be matched with float glass more easily.¹⁰

Distortion, clarity and sharpness

Similar to—and related to—surface quality are the measures of visual acuity through a given glass product. There are no “national and objective standards for evaluating visual distortion in glass assemblies,” according to Jeffrey C.F. Ng,¹¹ vice president at engineering firm Thornton Tomasetti, but he points to “existing methodologies for evaluating visual distortion in glass assemblies and specification criteria for ensuring the flatness of glass panels.” The Glass Association of North America (GANA) has undertaken research in recent years to show how “visual distortion in glass is a form of lens distortion,” Ng adds.

5 Keralite Select F measured values published by Vetrotech Saint-Gobain

6 <http://www.light-measurement.com/reflection-absorption/> (Gigahertz-Optik, Inc.); and SPIE, <http://spie.org/samples/PM229.pdf>, chapter 2, page 16

7 Center for Sustainable Building Research, University of Minnesota, <http://www.commercialwindows.org/transmittance.php>

8 Hunter Lab, <http://measuretruecolor.hunterlab.com/2013/10/17/measuring-reflected-color/#more-2515>

9 http://educationcenter.ppg.com/glasstopics/top_design_considerations.aspx

10 Vetrotech / Saint-Gobain

11 US Glass, www.usglassmag.com/AGG/BackIssues/2008/MayJune08/glassdistortion.htm

To evaluate distortion, one can use visual means, such as the naked eye, for single subject panels or comparative viewing of side-by-side mockups. A quantitative review can include comparisons of the peak-to-valley depth of the typical sine curve or roll-wave surface of the glass, measured with a three-point gauge or flat-bottom gauge.¹² The results of recent tests by manufacturers shows that glass ceramic products like Keralite SELECT have essentially “parallel glass surfaces with high surface quality and a minimum of distortion” due to novel processing technologies now in use.¹³

Shadow

Shadows and strain patterns can appear in heat-treated glass and other materials depending on lighting conditions. These may be caused by polarized light and may be called iridescence, or leopard spots or quench marks among glass fabricators, or anisotropy by building scientists. The apparent shadows may be caused by stresses during heat treatment. This generally not considered a defect, and it is distinct from the optical moiré patterns caused when one pane with a repetitive pattern is placed over another in poor alignment. Another possibility under certain lighting conditions is a reflection from a glass surface in vision glazing.

There are other considerations that affect the visual and aesthetic multifunctional qualities of glass ceramics. These included compatibility with metal framing, doors, and curtain wall types, as well as variables related to assembly and installation.

NOVEL GLASS CERAMICS WITH IMPROVED VISUAL VALUES

With these multifunctional attributes in mind, a new generation of glass ceramics has been introduced with measurable improvements in the visual/performance values that are required for high-quality architectural multifunction glazings.

One very recent achievement is a proprietary formulation by Vetrotech Saint-Gobain (Keralite Select)¹⁴ that incorporates a unique chemical composition and processing technique designed to make the panels more closely resemble typical float glass. The use of special raw materials and a unique manufacturing process help ensure these physical and optical properties that are close to those of standard float glass.

The Vetrotech Saint-Gobain formulation has been studied for a number of multifunctional performance characteristics. One of those is color, and Keralite Select has an amber hue as compared to other fire-rated glazings and glass ceramics.¹⁵ Glass color, determined by the material’s chemical composition, is often fine-tuned for an optimum level of multiple desired properties. Glass ceramics, in particular, have an unavoidable degree of hue or tint due the material makeup (embedded crystalline phase) and

TABLE 1. Color Rendering Index for Glass Ceramics and Comparable Values

Product Name	Make-Up	Color Rendering Index Ra (X65/2°)	Haze (A) [%]	Light Transmission TL (A) [%]	UV Transmission TUV (ISO 9050) [%]	Yellowness Index (DIN 6167) [%]
PLANILUX® Floatglass	5 mm unfilmed	98.8	0.1	89.5	68.0	0.4
KERALITE® Select Filmed	5 mm filmed	97.1	0.5	86.9	0.4	10
Brand X	5 mm filmed	96.5	1.0	83.5	0.3	11
Brand Y	5 mm with (surface applied) safety film	93.9	2.5	75.3	1.0	10

¹² Ibid

¹³ KERALITE POLISHED brief (North America), manufacturer’s own data

¹⁴ Vetrotech/Saint-Gobain

processing necessary to achieve fire-rated characteristics. Keralite Select has been optimized for optical and visual qualities as well as fire-protective performance characteristics. The visual properties that guided the formulation include: improved surface quality, high clarity and sharpness, and true color rendering.

The results for color testing, including proprietary and published data, shown in Table 1. Using the CIE method R96a color rendering test, the new glass ceramic is shown to compare well with other glass options with similar properties. They are also within an acceptable range for use near or adjacent to standard float glass and low-iron glass panels. The new glass ceramic formulation has also been shown to cause less color distortion, allowing a truer representation of colors.

TYPICAL APPLICATIONS AND MAXIMUM EXPOSED AREAS

The glass thicknesses available for the new generation of glass ceramic products (Keralite Select) are determined by material characteristics as well as the desired fire-protective qualities. The number of interlayers and films, if any, and overall monolithic glass thickness determine the fire rating, according to GANA.¹⁶ Depending on the application, glass ceramics achieve fire ratings from 20 minutes up to 180 minutes, and they are available in nominal thicknesses of 3/16 inch or 5/16 inch.

The building codes promulgated by AHJs, code officials and fire marshals should provide instruction or consultations for appropriate use of glass ceramic products in a given jurisdiction. Glass ceramics are tested with both a fire endurance test for the required minute rating immediately followed by a hose-stream test of the previously assembly. If used in hazardous locations, surface applied or interlayer films must provide the safety requirement from the Consumer Product Safety Commission (CPSC) 16 CFR 1201 Cat II (400 ft.-lbs.).

To be effective, the glass ceramic must be thin, light and economical. They must also have sufficient optical clarity at least to match non-rated glass or intumescent type multi-layered fire-rated products, for safe visibility levels in all situations. Typical

applications include hollow metal doors and frames, curtain wall assemblies, and especially developed insulated frame and door systems such as VDS Lite (by Vetrotech). These may include windows, transoms and sidelights with a maximum exposed height of 78 inches; for these assemblies, the maximum exposed area is 3,627 square inches for each individual glass lite. For a door application with non-temperature rise requirements, the maximum exposed width is 46.5 inches.

The new generation of glass ceramics provides a number of requisite beneficial qualities for architectural applications. The panels install into standard fire-rated frames and they are compatible with surface applied films or fully laminated finishing. The glass ceramic panels meet related standards, such as positive pressure testing requirements (UL10c/UBC 7-2) including Hose Stream Test, but also can help meet required U-values (and VLT and SHGC performance) as required for high performance applications.

SPECIAL APPLICATIONS AND RESULTS

With the novel benefits the new formulations of glass-ceramic fire glazings, a number of recent building projects have shown how to apply these and like products to full-glass walls, lobbies, retail settings and other instances where visual performance is essential. These may also include hospitality, healthcare, public safety, R&D and other applications where visual acuity through fire-rated glass walls is important. In addition, the novel glass ceramics present specific benefits of interest to architectural applications and building teams:

Glass matching

For glass matching in building types where fire-rated glass is mandated by code, one benefit of Keralite Select is the range of optical properties, colors and aesthetic variables that permit closer visual equivalency.

Premium locations

For high-value properties and applications where fire performance and aesthetics are equally important, this novel, multifunctional glass ceramic meets required fire ratings while also providing decorative and performance visual properties.

¹⁵ **Provide Keralite Select citation here.**

¹⁶ GANA Glazing Manual, Chapter 8

MULTIFUNCTIONAL CRITERIA FOR EVALUATING GLASS CERAMICS

In order to best evaluate the multifunctional benefits of a given glass ceramic, a review of relevant literature shows that it is essential to include the full gamut of visual performance criteria. These include a close visual match to any standard float glass specified for same project, as well as manufacturer criteria for the variables discussed in this white paper. These can be initially determined using simple visual examination, such as by evaluating glass samples or mockup assemblies.

The fire-rated glass ceramics should meet prevailing manufacturer quality standards for such performance traits as surface variability and imperfections. In addition, the building teams will review specified properties and standards (or minimum values) for aesthetic and visual variables reviewed in this paper, such as:

- True color
- Reflectivity
- Surface quality
- Distortion
- Clarity or sharpness
- UV absorption
- Light transmission/light scattering
- Cloudiness
- Haze
- Shadow

CONCLUSION

There are both subjective and objective benefits to consider with the introduction of the multifunctional polished glass ceramics discussed in this white paper. Some of these are also comfort benefits because they allow for ease of sight and visual performance by occupants and visitors to buildings using the polished glass ceramics. These benefits are a reality for fire-rated applications today: The glass ceramic delivers better measurable values for visual and performance criteria, which are increasingly important to building teams.

Selection criteria have been presented that allows for improved evaluations of the visual performance quality of glass ceramics, and many have official testing norms or standards that help in these comparisons of fire-rated glazing materials.

Among the most important qualities to consider in a multifunctional glass ceramic are: superior surface quality, with parallel glass surfaces with high surface quality and a minimum of distortion; superior clarity, displaying true colors; and maximum effective daylight transmittance, to allow the harnessing of natural daylighting for improved energy efficiency. Another valuable quality is the ability to have very low or zero UV-transmittance. The new generation Keralite SELECT offers these qualities for architectural applications, with improved surface quality resulting in superior clarity, sharpness and color accuracy.

About Vetrotech Saint-Gobain

Vetrotech Saint-Gobain is a leading manufacturer of fire-rated glass and fire-resistant door, frame, window and curtain wall systems in the U.S. A member of the Saint-Gobain Group, it is Europe's largest producer and processor of glass and a world leader in the habitat and construction markets, and present in 64 countries. Saint-Gobain may best known for its joint venture relationship with Corning Glass.

Vetrotech Saint-Gobain has been producing fire-rated glass and framing systems (since 2003) at its state-of-the-art facility near Seattle, Washington since 2000. Vetrotech has played an important role in standards development for fire-resistant safety glass with its first UL listing in 1983.

Our promise to our customers includes contributing to the creation of uniqueness in their projects and helping them to reply the complex challenges which we all face in the fast moving building industry. We believe it is our responsibility to develop not just quality & multifunctional products, but also reliable services on a continual basis. Our innovative developments and cutting-edge production facilities deliver solutions covering your very need. With pioneering passion, know-how and innovation we comply with architectural demands for aesthetics, performance and comfort while never forgetting our ultimate mission of protecting life and property in living places and dedication to preserving our environment.



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