Structural Glazing Silicone in Gas Filled Insulating Glass - Main Airport Center

Axel H. Giesecke, Dr.Andreas T. Wolf, Dow Corning GmbH
Rheingaustrasse 34, D-65201 Wiesbaden, GERMANY

Key Words

1=Structural Silicone Glazing (Structural Glazing) 2=Insulating Glass Unit (IG-Unit) 3=Silicones 4=Gas Leakage

Abstract:

Often the objective of architects and investors for commercial buildings is to achieve an aesthetically pleasing, "smooth" glass-clad curtain wall that also provides excellent thermal efficiency. In order to enable the IG-seal to be freely exposed to the weather (sun and rain) without shading or coverage by a metal frame, the edge seal needs to be highly weather resistant. Silicone is the only adhesive, which provides such properties. Combining the requirements for an aesthetically pleasing glass façade with those for a highly energy-efficient building requires the use of argon gas-filled IG units with silicone secondary seals.

For the project "Main-Airport-Center – Frankfurt", four different industrial partners and co-suppliers cooperated to develop a silicone edge seal system capable of retaining argon gas far in excess to the requirements set out in EN 1279.

In a continuing effort to push the envelope of a creative design architects and building owners are looking to glass enamel coatings. In support of this trend a working group of individuality specialized industry experts has now proven that structurally functional bonding on glass enamel coatings is technically feasible. A general approval by the demanding German building authorities confirms the safety and reliability of these techniques.

The more complex the design for a state-of-the-art building project is, the more important a close cooperation between all involved industrial and external parties is in order to successfully meet the requirements set out by the investor and architect.

Introduction

The "MAC" Main-Airport-Center, a multi-functional business center located in the neighborhood of the Frankfurt International Airport, has been architecturally well designed to blend in with the surrounding city forest. Silicone Structural Glazing (SSG) Technology in combination with insulating glass units (IGU) are utilized in an innovative, two-sided structural glazing design resulting in the unique transparency of the glass façade combined with the highly insulating functionality and allowing construction of the curtain wall in a cost-competitive manner.

To meet the high insulation requirements, the inter-pane space needed to be argon gas filled. In the past it had proven to be difficult, at best, to meet the gas loss requirements for argon filled IG-units, such as defined in EN 1279 [1], with a silicone secondary edge seal. On the MAC project this ambition was realized by the cooperation of several industrial companies developing customized technical solutions within a short time span. Four different industrial partners / co-suppliers developed a silicone edge seal system capable of retaining argon gas far in excess to the requirements set out in EN1279 [1].

Furthermore, in some areas of the façade, creativity in the design and high aesthetic expectations required the use of a decorative glass coating based on glass enamel combined with the Structural Glazing Technology. Therefore the durability of adhesion of a silicone structural glazing sealant on the decorative coating needed to be confirmed and the system as a whole needed to be approved.

Figure 1
The Main Airport Center

Weather resistant sealants and adhesives

The design details for the MAC-Project (Figure 1) show that the IGU dual seal as well as the Structural Glazing Adhesive are fully exposed to the weather (Figure 2 and 3).

The weather causes several physical and chemical stress factors, which need to be taken into consideration in order to design a long-lasting and reliable façade capable of protecting the investment of the building owner. Several examples of these stress factors are shown in Table 1.

The above mentioned construction design details clearly necessitate a dual seal system for the IGU, which is capable of resisting the climatic stress factors. The dual-sealed IG units were required to pass the new EN 1279, especially with regard to the gas loss rate, in order to ensure a high insulating performance over the long service-life of the IGU.

Silicone sealants are based on polydiorganosiloxane polymer, typically polydimethylsiloxane (PDMS) polymer, which has a completely different polymer structure than organic polymers, such as used in polysulfide or polyurethane sealants. The structure of silicone polymer - Polydimethylsiloxane (PDMS) – is shown in Figure 4.

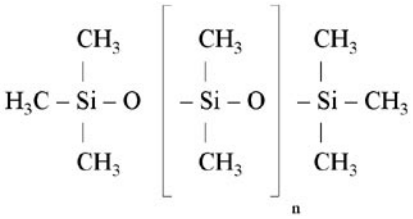


Figure 4
Formula of Polydimethylsiloxane (PDMS)

The key-differentiating feature of PDMS polymer is its inorganic siloxane (Si-O-Si) backbone, which provides the outstanding durability, and, combined with the organic methyl –groups, the excellent elastomeric properties. The PDMS polymer has a special Molecule-Structure which is shown in Figure 5.

The unique polymer structure provides silicones with an inherent durability, resistance against UV-radiation (see Figures 6 and 7), high performance properties, which are stable over a wide temperature range, and as a result, outstanding weather resistance [8]. (renumber references) These unique properties are the reason why silicones are the material of choice when high quality and high durability sealants are required.

IG units with silicone edge according to EN1279

Silicone single-sealed IG units are known to have higher gas losses (permeability) than allowed by EN 1279-3. The same is true for single-sealed units based on polysulfide or polyurethane-sealants,

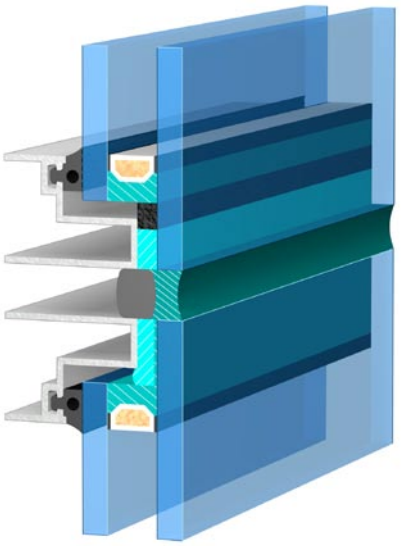


Figure 2
Design Sketch-Unit,
Stepped IG-Unit as Structural Glazing

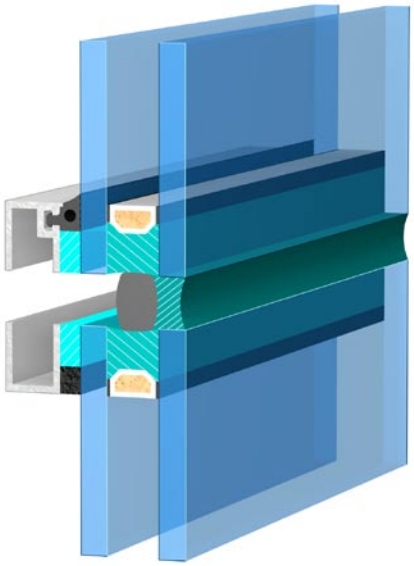


Figure 3
Design Sketch,
Symmetrical IG-Unit as Structural Glazing

Sun Light:	
UV-Radiation	High energy – capable to de-bond molecules
Visible Light	Temperature effect
IR-Radiation	Significant Temperature effect
Rain / Water:	
Moisture	Moisture load
Air:	
SO_x	aggressive chemical – capable to cause chemical reaction
NO_x	aggressive chemical – capable to cause chemical reaction
O_2 / Ozone	aggressive chemical – capable to cause oxidations

Table 1
Environmental Stress Factors

Figure 5
PDMS Molecule-Structure

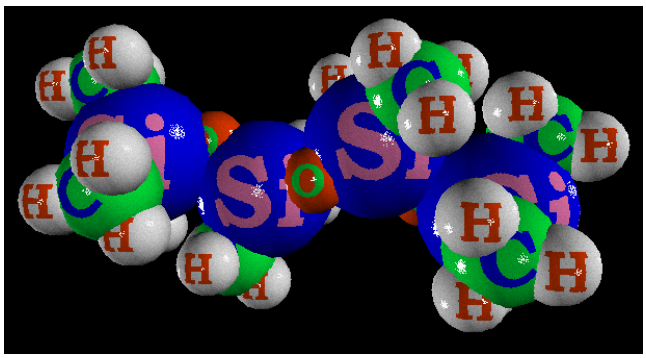


Figure 6
Solar Spectrum

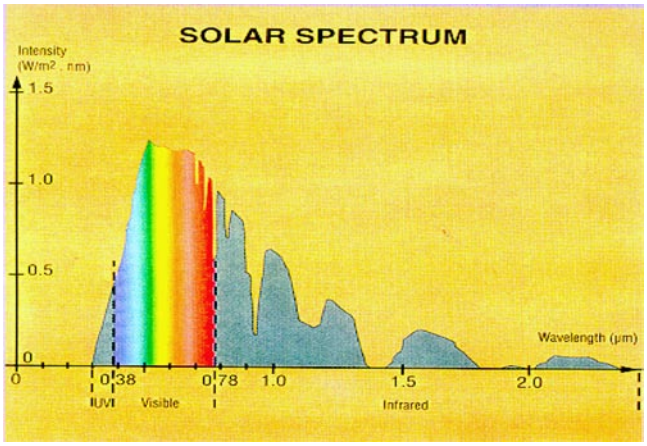
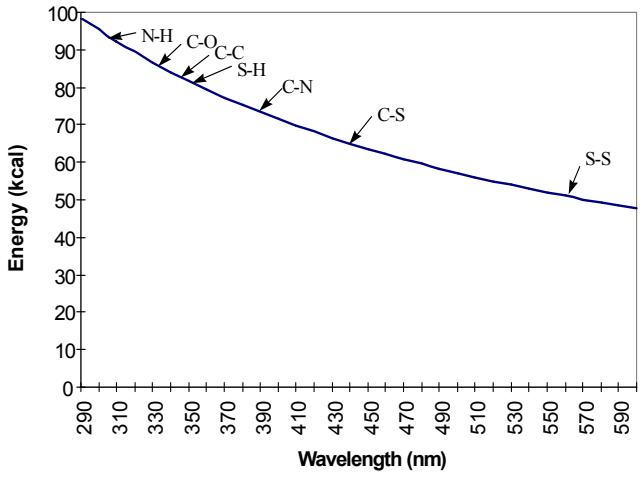


Figure 7
Wavelength versus Energy



however, silicones have the highest gas permeability amongst these three materials [3]. Therefore, nowadays a dual seal system represents the state of the art in IG edge-seal technology in order to meet the longevity (service life) requirements according to EN 1279. Both seals within this dual seal system have their own function. The primary seal provides the sealing barrier for water vapour as well as for fill gases (such as air or inert noble gases). The primary seal limits the amount of water vapour that is capable of penetrating into the inter-pane space (diffusion into the IGU) and also reduces the loss of fill gases from the inter-pane space to the environment (diffusion out of the IGU). An additional function of the edge-seal is to dry the gas incorporated between the glass panes. Therefore usually a desiccant is included in the spacer bar. Primary seals are usually based on polyisobutylene (PIB) and are used in combination with metal or plastic spacer bars. However, the Thermo-Plastic Spacer (TPS®) system combines the functions of the primary seal and the spacer bar into one material by incorporating the desiccant into the PIB matrix.

As the PIB (primary seal) is only physically attached by Van der Waals Forces to the glass surface the secondary seal needs to provide the long-term adhesion and maintain the geometry of the edge-seal.

Silicone secondary edge sealants for IG units develop durable chemical bonds to glass substrates and are therefore capable of providing excellent, long-lasting adhesion and fixation of the edge-seal.

Combining the strengths in the properties of the different materials with a clever system design and expertise in the production of IG units is key to success. The cooperation of spacer bar producers Erbslöh and RollTech and the spacer key manufacturer Eduard Kronenberg together with Dow Corning as silicone supplier and BGT as experienced producer of commercial IG units resulted in a high quality commercial IG unit with a silicone IG edge-Seal System, which by far exceeds the requirements set out by EN 1279 (parts 2 and 3). Especially the gas retention was proven to be very impressive for the jointly developed system (see Tables 2 and 3).

The Insulating Glass System 1 was designed with a Stainless Steel Spacer, which was bended on all four corners and linked together with one key on a linear side (not in the corner). For the PIB application a special procedure was developed by the glass manufacturer. Table 2 shows the test results of this system with the stainless steel spacer.

Glass and Stainless Steel have a quite similar temperature coefficient while the coefficient for glass and aluminium is quite different. Therefore it is expected to be more difficult, if not impossible at all, to meet the requirements for the maximum gas leakage according to EN 1279 Part 3. The especially developed systems shows that it is possible to meet the requirements for the maximum gas leakage according to EN 1279 Part 3, even with an Aluminium spacer in combination with silicones as secondary edge sealant. The Insulating Glass System 2 was designed with an Aluminium Spacer, which was bended on all four corners and linked together with one key on a linear side (not in the corner). The same PIB application special procedure was applied by the glass manufacturer. Table 3 shows the test results of this system with the aluminium spacer.

The maximum allowed gas loss rate according to EN1279-3 is 1%. The realized gas loss rates are substantially below 1%, i.e. between 0.1% and 0.2%!

Specially designed secondary IG silicone sealants are the only materials meeting the requirements of EN1279 as well as the requirements of ETAG 002 [4] and prEN 13022 [5]

IG- System 1	Test 1		Test 2	
Gas-Type	Argon		Argon	
Sample No	4	5	4	5
Measured Gas Concentration c_i [Vol.-%]	94,3	93,8	94,3	94,3
Nominal Gas Concentration $c_{i,o}$ [Vol.-%]	90	90	90	90
Gas loss rate L_i	0,17	0,22	0,19	0,25

Table 2
Gas loss rates according to EN 1279-3 for the Stainless Steel Spacer System with Silicones [9]

IG- System 2	Test 1		Test 2	
Gas-Type	Argon		Argon	
Sample No	3	5	3	5
Measured Gas Concentration c_i [Vol.-%]	95,2	95,2	95,2	95,2
Nominal Gas Concentration $c_{i,o}$ [Vol.-%]	90	90	90	90
Gas loss rate L_i	0,12	0,22	0,12	0,15

Table 3
Gas loss rates according to EN 1279-3 for the Aluminium Spacer System with Silicones [10]

Structural Glazing at the Main Airport Center

The Silicone Structural Glazing Technology allowed realization of the vision of the investor and architect to have a "lean framework". The two-sided structural glazing design provides the unique transparency to the glass façade combined with high insulation functionality and allows construction of the curtain wall in a cost-competitive

manner. To ensure the aesthetics and functionality of the design, an intensive cooperation between all parties involved is necessary. For the MAC project, the curtain wall company worked closely with the Structural Glazing Solution Provider (sealant and expertise) during the planning and realization phase in order to ensure that all requirements are met or exceeded for a Structural Glazing Design according to the most up-to-date "state of the art" as described in ETAG 002.

Within Europe, the European Organisation for Technical Approvals (EOTA) is the body that coordinates the development of European Technical Approval Guidelines (ETAGs) and issues European Technical Approvals (ETAs). Between September 1998 and May 2002, EOTA has published ETAG 002 Structural Glazing Systems in three parts [4].

ETAG 002 is the European Technical Approval Guideline for the Structural Glazing Technology, which ensures that the six main requirements of the European Construction Products Directive [6] are met. The Construction Products Directive contains essential requirements relating to 'materials intended for construction.' Materials intended for construction are defined in the directive as those products that are manufactured to form a permanent part of structures. Structures refers to both building and works of art. The directive came into force on June 27, 1991. At present, the directive is in a transitional period since the European Commission still has to establish when the directive will become mandatory. Materials intended for construction must comply with the fundamental regulations during an economically relevant lifetime and provided regular maintenance is carried out. These fundamental regulations are subdivided into the following six aspects:

- mechanical strength and stability
- fire safety
- hygiene, health and environment
- safety of use
- sound nuisance
- energy savings and heat retention.

It is important to note that the ETAG 002 guideline covers four different types of two- and four-sided structural glazing systems. These systems are differentiated by the presence or absence of safety retaining devices and/or mechanical dead-load supports. National regulations are expected to determine which one of these systems will be allowed in each member country. A construction product with an ETA, satisfying the Attestation of Conformity provisions, can carry a CE marking and can be placed on the market anywhere within the EU member (EEA) countries. Recently, the first structural silicone glazing sealant has been endorsed with the CE mark based on its conformance with the EOTA requirements.

Usually the sealant supplier is responsible for the Structural Glazing Silicone to meet all the requirements according to ETAG 002. The compliance with ETAG 002 may be proven with a CE-Mark. In addition, the sealant supplier is usually providing several adhesions and performance tests during planning and realization and further checks the design calculation for the Structural Glazing Detail to ensure conformity with the ETAG requirements. Furthermore, a detailed Quality Management Support may be provided by the sealant supplier to the curtain wall company, assisting in the realization of a superior Quality Bond façade.

Chemical compatibility between the different material components, especially for a curtain wall design involving IG units in a SSG design, should be a topic of focused consideration. Any incompatibility can have a negative impact on the service-life of the IG unit or the SSG bonding [7]. All materials used in the design should be proven to have long-term compatibility.

In the MAC project, for aesthetic reasons, the SSG bonding was partially required to be on enameled glass. Therefore, the adhesion of the structural glazing sealant on the enameled glass substrates had to be proven to meet the requirements according to ETAG 002. A working group of experts from different industries, composed of producers of glass enamels, independent institutes, producers of enameled glass and a supplier of Structural Glazing Solutions, has been able to examine the correlation between the formulation of the glass enamels, production parameters of enameled glass, and the adhesion of structural glazing sealants. The findings of this experienced working group resulted in the general approval by the German Building Authorities (DIBT-Berlin) for structural glazing application of silicone sealants on thousands of glass enamel colors based on the ETAG 002 requirements. This approval is available under the reference No. Z-70.1-75 at the DIBT-Berlin [8].

Summary

The objective of architects and investors for commercial buildings often is an aesthetically pleasing, "smooth" glass-clad curtain wall having a high insulating value. In order to enable the IG-seal to be freely exposed to the weather (sun and rain) without shading or coverage by a metal frame, the edge seal needs to be highly weather resistant. Silicone is the only adhesive, which provides such properties. Combining the requirements for an aesthetically pleasing glass façade with those for a highly energy efficient building requires the use of argon gas-filled IG-units with silicone secondary seals.

In the past it had proven to be difficult, at best, to meet the gas loss requirements for argon filled IG units, as defined in EN 1279, with a silicone secondary edge seal. On the project "Main-Airport-Center – Frankfurt", four different industrial partners / co-suppliers cooperated to develop a silicone edge seal system capable of retaining argon gas far in excess to the requirements set out in EN 1279.

Creative design and decoration is very often an additional requirement for aesthetic reasons. A working group of differently specialized industry experts has now proven that structurally functional bonding on glass enamel coatings is technically feasible. A general approval by the demanding German building authorities, DIBT-Berlin, confirms the safety and reliability of such design.

The more complex the design for a state-of-the-art building project is, the more important a close cooperation between all involved industrial and external parties is in order to successfully meet the requirements set out by the investor and architect.

References

[1] EN1279 – Glass in Building – Insulating Glass Units – Part 3; Long Term test Method and Requirement for Gas Leakage Rate and for Gas Concentration Tolerances, CEN European Committee for Standardization, Brussels, Belgium, 2000

[2] Wolf A.T., "Durability of Silicone Sealants", Durability of Building Sealants RILEM State-of-the-Art Report, A.T.Wolf, Ed., RILEM Publication, Bagnaux, France 2000, pp. 253-273

[3] Wolf, A.T., "Silicone Sealed Insulating Glass Units", Proceedings of ISAAG - International Symposium on the Application of Architectural Glass - Engineering and architectural design of glass - Munich, Germany, November 15-16 2004, Universität der Bundeswehr München, Neubiberg, Germany (2004)

[4] ETAG 002 – European Guideline for Technical Approval for Structural Silicone Glazing Systems SSGS, Part 1 (24 September 1998), Part 2 - Coated Aluminium Systems (16 January 2002), Part 3 - Systems incorporating profiles with thermal barrier (25 May 2002), EOTA, European Organization for Technical Approvals, Avenue des Arts 40, 1040 Brussels, Belgium

[5] Pr-EN 13022 –2, Glass in Construction – Structural Sealant Glazing – Part 2, Product Standard for Ultraviolet Resistant Sealant and Structural Sealant, CEN European Committee for Standardization, Brussels, Belgium, 2002

[6] The Council of the European Communities 1988, Council directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products, The Council of the European Communities, Brussels. 89/106/EEC.

[7] Giesecke, Axel H., "Chemical Cocktail at the Insulating Glass Edge Sealant", Glas Fenster Fassade, No. 09 / 2002, Germany

[8] Z-70.1-75, "Allgemeine bauaufsichtliche Zulassung" for „Enamelled Heat Strengthened Glass for Structural Glazing with Dow Corning 993", DIBT-Berlin, 21st July 2004

[9] Test Certificate No.: 3/3113/107-4/1, 07.11.2003, Landesmaterialprüfamt Sachsen-Anhalt, Grosse Steinernetischstrasse 4, D-39104 Magdeburg, GERMANY

[9] Test Certificate No.: 3/3113/105-4/1, 07.11.2003, Landesmaterialprüfamt Sachsen-Anhalt, Grosse Steinernetischstrasse 4, D-39104 Magdeburg, GERMANY