

# Success with silicones

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Often the objective of architects and investors for commercial buildings is to achieve an aesthetically pleasing, smooth glass-clad curtain wall with thermal efficiency. For the IG-seal to be freely exposed to the weather without shading or coverage by a metal frame, the edge seal needs to be highly resistant to the weather. Silicone is the only adhesive that 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 a continuing effort to drive creative design, architects and building owners are looking to glass enamel coatings. In support of this trend, a working group of specialised industry experts has now proven that structurally functional bonding on glass enamel coatings is technically feasible. A general approval by stringent German building authorities confirms the safety and reliability of these techniques.

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

For the Main Airport Centre – Frankfurt project, four different industrial partners and co-suppliers worked to develop a silicone edge seal system, capable of retaining argon gas above and beyond the requirements set out in EN 1279.

## The big MAC

The Main Airport Centre (MAC), a multi-functional business centre located in the vicinity of Frankfurt International Airport, has been architecturally designed to blend in with its surroundings. Silicone Structural Glazing (SSG) Technology was used in combination with insulating glass units (IGU) in an innovative, two-sided structural glazing design. The unique transparency

of the glass façade, combined with its highly insulating functionality, has enabled construction of the curtain wall in a cost-competitive manner.

To meet the high insulation requirements, the interpane space needed to be argon gas filled. In the past it had proved 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 MAC project, this ambition was realised by the co-operation of several industrial companies that developed customised technical solutions within a short time-span.

In some areas of the façade, creativity in design and high aesthetic expectations required the use of a decorative glass coating based on glass enamel combined with structural glazing technology. Therefore, the adhesion durability of a silicone structural glazing sealant on the decorative coating needed confirmation and the whole system required approval.

## Weather resistant sealants

Weather patterns produce several physical and chemical stress factors, which need to be taken into consideration when designing a long-lasting and reliable façade, to cover the investment of the building owner. Several examples of these stress factors are shown in table 1 below.

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

**Table 1: Environmental stress factors**

### Sun Light:

UV-Radiation	High energy, capable of de-bonding molecules
Visible Light	Temperature effect
IR-Radiation	Significant temperature effect

### Rain / Water:

Moisture	Moisture load
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### Air:

SOX	aggressive chemical – capable of causing a chemical reaction
NOX	aggressive chemical – capable of causing a chemical reaction
O2 / Ozone	aggressive chemical – capable of causing oxidation

completely different polymer structure than organic polymers, such as used in polysulfide or polyurethane sealants. The key differentiating feature of PDMS polymer is its inorganic siloxane (Si-O-Si) backbone, which provides outstanding durability. Combined with the organic methyl groups, it has excellent elastomeric properties.

The unique polymer structure provides silicones with an inherent durability, resistance against UV-radiation, high performance properties, which are stable over a wide temperature range, and thus weather resistance. 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**

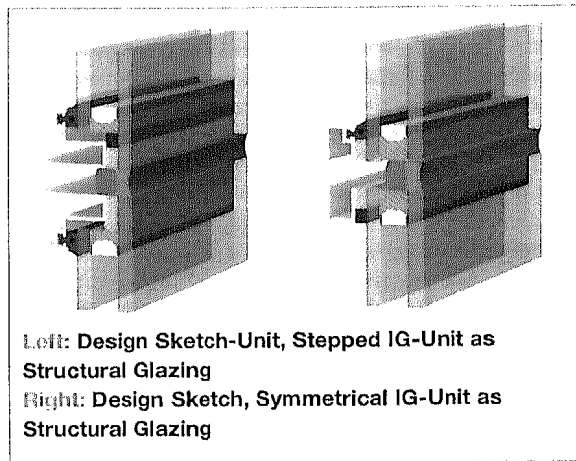
Silicone single-sealed IG units are known to have higher gas losses (permeability) than allowed by EN 1279-3. The same is true for single-sealed units based on polysulfide or polyurethane-sealants. However, silicones have the highest gas permeability amongst these three materials. Therefore, a dual seal system now represents state of the art IG edge-seal technology 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 interpane space - diffusion into the IGU - and also reduces the loss of fill gases from the interpane 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. 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 force to the glass surface, the secondary seal needs to provide long-term adhesion and maintain the geometry of the edge-seal. Silicone secondary edge sealants for IG units develop durable chemical bonds with glass substrates and are therefore capable of providing 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. Spacer bar producers Erbslöh and RollTech and spacer key manufacturer Eduard Kronenberg have combined together with Dow Corning as silicone supplier and BGT as a producer of commercial IG units. This has resulted in a high quality commercial IG unit with a silicone IG edge-seal system that exceeds the requirements set out by EN 1279 (parts 2 and 3). Gas retention was proven to be very impressive for the jointly developed system (see tables 2 and 3).



Left: Design Sketch-Unit, Stepped IG-Unit as Structural Glazing

Right: Design Sketch, Symmetrical IG-Unit as Structural Glazing

The Insulating Glass System 1 was designed with a stainless steel spacer, which was bent on all four corners and linked together with one key on a linear side, but not in the corner. The glass manufacturer developed a special procedure for the PIB application. 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, to meet the requirements for maximum gas leakage according to EN 1279 Part 3. The especially developed systems shows that it is possible to meet the requirements for 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

**Table 2: Gas loss rates according to EN 1279-3 for the stainless steel spacer system with silicones**

IG- System 1	Test 1	Test 2		
Gas-Type	Argon	Argon		
Sample No	4	5	4	5
Measured Gas Concentration $c_{m}$ [Vol.-%]	94.3	93.8	94.3	94.3
Nominal Gas Concentration $c_{n}$ [Vol.-%]	90	90	90	90
Gas loss rate $L$	0.17	0.22	0.19	0.25

**Table 3: Gas loss rates according to EN 1279-3 for the aluminium spacer system with Silicones**

IG- System 2	Test 1	Test 2		
Gas-Type	Argon	Argon		
Sample No	3	5	3	5
Measured Gas Concentration $c_{m}$ [Vol.-%]	95.2	95.2	95.2	95.2
Nominal Gas Concentration $c_{n}$ [Vol.-%]	90	90	90	90
Gas loss rate $L$	0.12	0.22	0.12	0.15

aluminium spacer, bent on all four corners and linked together with one key on a linear side, but again not in the corner. The same special PIB application procedure was carried out 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 realised 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 and prEN 13022.

### Structural glazing legislation

SSG Technology has allowed the vision of the investor and architect to have a "lean framework". The two-sided structural glazing design provides transparency to the glass façade combined with high insulation functionality, enabling the 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 realisation phase. This was to ensure that all requirements are met or exceeded for a structural glazing design according to the most up-to-date technology 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). It issues European Technical Approvals (ETAs). Between September 1998 and May 2002, EOTA has published ETAG 002 Structural Glazing Systems in three parts.

ETAG 002 is the European Technical Approval Guideline for structural glazing technology, which ensures that the six main requirements of the European Construction Products Directive 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 refer to both building and works of art.

This 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 realisation. With further checks, the design calculation for structural glazing detail will ensure conformity with the ETAG requirements. Furthermore, the sealant supplier may provide detailed quality management support to the curtain wall company, assisting in the realisation of a superior quality bond façade.

### SSG bonding

Chemical compatibility between 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. 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 enamelled glass. Therefore, the adhesion of the structural glazing sealant on the enamelled 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 enamelled glass and a supplier of structural glazing solutions was established. This group has been able to examine the correlation between the formulation of the glass enamels, production parameters of enamelled 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 applications of silicone sealants on thousands of glass enamel colours based on the ETAG 002 requirements. This approval is available under reference number Z-70.1-75 at the DIBT-Berlin. ■

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