SUMMARY ANALYSIS OF THE DIFFERENT FAMILIES OF WARM EDGE SPACERS AVAILABLE ON THE MARKET:

Guide to making an informed choice

INTRODUCTION

Ï Reducing energy consumption is undoubtedly a must today. This priority factor has automatically involved the frame industry as well, resulting in the requirement for windows with increasingly lower thermal transmittance values, Uw [W/m^2 K]. The new generation of spacers used in the "warm edge" insulating glass units has played an important role in the achievement of these objectives.

"Warm edge" spacers are defined to be all those spacers built with materials whose coefficient of linear thermal conductivity (»), significantly lower than that of the conventional aluminum spacer bar, contributes to improving the performance of the window by reducing the thermal bridge at the edge. Various kinds of materials are involved depending on the type of spacer (flexible foams, thermoplastics, plastic/metal hybrids, stainless steel).

When choosing the spacer, however, many factors must be considered (environmental, constructional, regulatory and energy factors), and this analysis will demonstrate how the best choice can be made by considering these factors as a whole and also based on the type of application intended for the glass units.

SPACERS CURRENTLY AVAILABLE ON THE MARKET

Currently warm edge spacers can be divided into three groups:

Group 1: Flexible Spacers

Pliable, flexible thermoplastic and/or silicone-based materials with incorporated molecular sieves. Among these, the following stand out :

a) The butyl hot melt types without any additives. Example: TPS

b) The silicone types, cold-applied, which in their most advanced version are butylated laterally with the back in contact with the outer sealant. Example: SS Triseal

Group 2: Plastic/Metal Hybrid Spacers

Plastic materials (PolyCarbonates, PolyPropylene, etc.) combined with low metal shims that should have the same working procedures as the conventional aluminum spacer (cutting or bending, butylating, drilling for the introduction of desiccants and gas). Examples: Chromatech Ultra, Swisspacer, Thermix TXN, TGI.

Group 3: Stainless Steel Spacers

Materials in stainless steel alone whose working procedure is also similar to that of aluminum spacers, but with some special measures taken due to the use of a completely different material.

BENEFITS OF USING WARM EDGE SPACERS

The widely established and recognized benefits of warm edge spacers are the following:

1) Energy savings
2) Environmental benefits with lower CO_2 emissions
3) Reduction of surface condensation on the insulating glass
4) Reduced risks of mold formation on the frames, thereby extending their service life
5) Contact surfaces of the window are less cold and thus more comfortable

Aluminum, on the contrary, is an excellent heat conductor. It actually creates a thermal bridge which lowers the temperature in the perimeter zone of the glass unit, favoring condensation and thus increasing the risk for mold to develop on the frame, deterioration of the frame, degradation of the sealants and consequent shortened service life of the insulating glass unit.

These effects are eliminated or at least minimized with the use of warm edge spacers.

1-2) ENERGY SAVINGS – ENVIRONMENTAL BENEFITS

Using warm edge spacers leads to a 10% reduction in the thermal transmission of the window and a consequent reduction of the heating costs, as well as lower CO_2 emissions with relative environmental benefits.

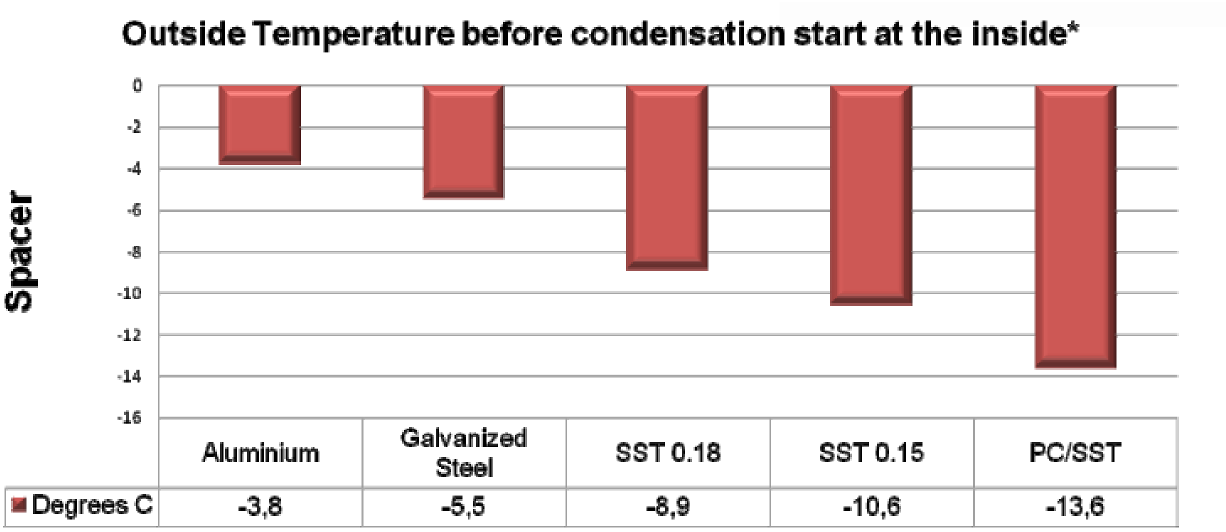
An example of the energy and environmental benefits that can be obtained by using warm edge spacers:

	Per year	**In 25 years**
Fuel savings	**60 liters**	**1,500 liters**
CO_2 Emissions reduction	**100 m^3**	**2,500 m^3**

3-4-5) CONDENSATION, MOLD AND SURFACE TEMPERATURE EFFECTS

The condensation on the surface of the window begins when the glass temperature falls below the dew point.

The following graph illustrates, for the different spacer types, the outside temperatures required for condensation to start under normal conditions (room temperature equal to 20 °C with 50% relative humidity).



*Metal frame Uf = 2,05 W/m^{2}K. Inside: 20^o C, 50 % RH, dew point 9,3^o C

The graph clearly shows that the condensation cannot be eliminated altogether, but the use of warm edge spacers can significantly reduce the condensation effect, which also benefits the frame by extending its service life.

Warm edge spacers have a remarkably positive effect on the surface temperature of the internal glass measured near the edge.

CRITICAL FACTORS OF WARM EDGE SPACERS

The warm edge spacer cannot be chosen based on the possible energy savings alone. The choice must also take into consideration the following critical factors, more or less relevant depending on the spacer type:

1) Mechanical stability and thermal expansion

2) Compatibility with the edge sealants

3) Adhesion to the outer sealant (UNI EN 1279/6)

4) Difficulty of use in production and greater controls (UNI EN 1279/1: System Description)

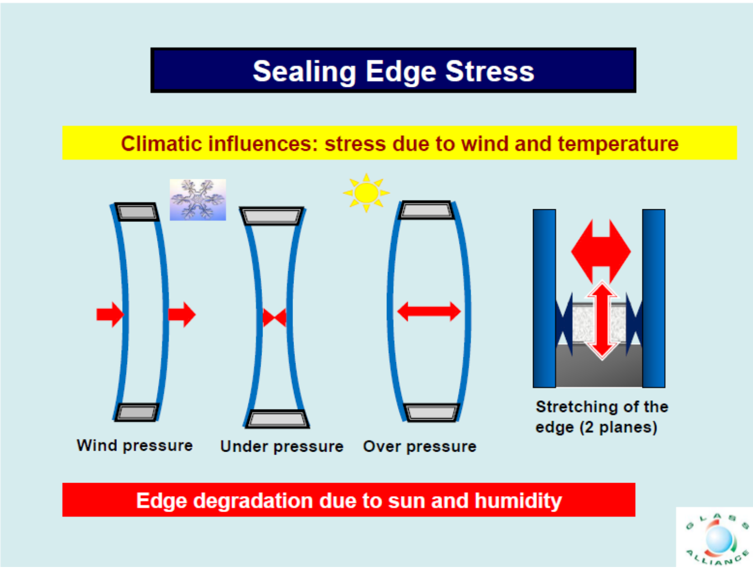
5) Compliance with the standards, particularly UNI EN 1279

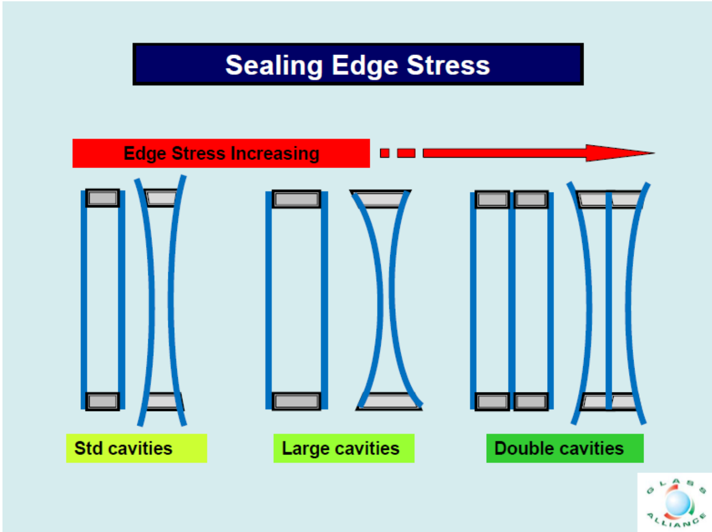
6) Moisture penetration (UNI EN 1279/2 and UNI EN1279/4) and gas leakage (UNI EN 1279/3)

7) The È value and energy savings

1) MECHANICAL STABILITY AND THERMAL EXPANSION

As is well known, insulating glass units are constantly stressed at the edge by weather conditions, and these stresses increase according to the cavity size and the number of cavities.





Factors like mechanical stability and thermal expansion of the materials making up the warm edge spacers naturally play an important role in these stresses, minimizing and/or increasing them depending on their characteristics.

Materials with high mechanical stability and low thermal expansion significantly reduce the stresses exerted on the primary and secondary sealants making up the edge of the insulating glass unit. Vice versa, the higher the thermal expansion of the spacer, the more significant the stress exerted on the edge sealants, with possible negative effects on the service life of the window.

THERMAL EXPANSION OF THE MATERIALS

Materials	Linear expansion coefficient	Expansion at 60 °C for glass unit with length of 2000 mm	Difference in expansion for glass
Glass (reference)	$9 * 10^{-6}$	1.08	
Steel	$12 * 10^{-6}$	1.44	0.36
Stainless Steel	$16 * 10^{-6}$	1.92	0.84
Aluminum	$24 * 10^{-6}$	2.88	1.80
Polycarbonate (PC)	$65 * 10^{-6}$	7.80	6.72
Polypropylene (PP)	$150 * 10^{-6}$	18.00	16.92

In general, except for those in stainless steel, all warm edge spacers actually increase the stresses on the edge of the insulating glass unit until reaching extreme cases like that shown in the photograph below (spacer distorted due to thermal expansion):

Finally, the mechanical stability of the spacers is a factor which also affects their processability. Frames which have low mechanical stability are more problematic during assembly in the insulating glass unit, often failing to satisfy geometric tolerances at the edge and resulting in seal defects. This problem is emphasized with the growing expansion of the glass and spacer, leading to butyl detachment and thus compromising the glass unit's most important protection.

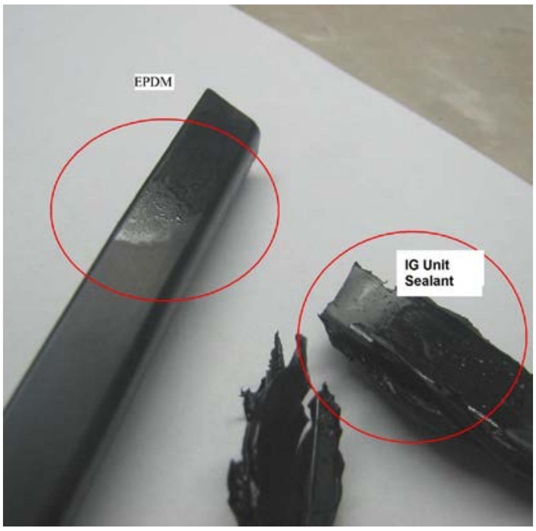
2) COMPATIBILITY WITH THE EDGE SEALANTS

One of the most common problems in the field of production and marketing of insulating glass units is the compatibility between the sealants and the materials used or additional accessories like spacers, separators, angle bars, plastic cables, connectors, compound glass resins, etc.

The assembly of the various components involves materials and sealants having a wide variety of physico-chemical characteristics and belonging to a broad range of chemical families.

Detailed studies conducted at several laboratories including our own, in compliance with the IFT-Guideline DI-01/1 (§ 4.4 – VE-05/1,) have allowed the study and identification of incompatibility problems between edge sealants and the spacer. The contact tests carried out under the conditions required by the guideline have allowed us to interpret and identify any losses of sealant adhesion to the substrates, the presence of oiliness, dissolving and yellowing.

Thus particular care must be taken with spacers containing organic parts which may then react with the edge sealants of the insulating glass unit, i.e., mainly the spacers belonging to Groups 1 and 2.



3) ADHESION TO THE OUTER SEALANT

Adhesion tests carried out with spacers belonging to Group 1 generally yield results which are second-rate or barely acceptable.

Similar results have been found with anodized and painted metal spacers.

Furthermore, it should be noted that the tensile test required by standard UNI EN 1279/6 (Annex F.3) with the use of Group 1 spacers may be difficult or infeasible.

The sample preparation procedure, equipment and execution of the test must ensure that the load is applied in a constant manner, the spacer does not buckle and the sealant is always under tensile stress.

4) DIFFICULTY OF USE IN PRODUCTION AND GREATER CONTROLS

4.1 Difficulty of Use

The transition from classic aluminum spacers to warm edge spacers includes:

1) For spacers belonging to Group 1, an investment in special machinery.

2) For those belonging to Group 2, an adaptation of the machinery and replacement of the blades with a different setup for the procedures for cutting, bending and drilling the groove where necessary.

Note: The high flexibility and particular shape of the materials belonging to Groups 1 and 2 make large frames harder to handle and require careful verification of the quantity and continuity of the edge seam.

3) For the materials IN Group 3, an adaptation of the profile bender and/or cutting blades is necessary.

4.2 Production Controls

As regards production controls, the following must be considered:

1) For Group 1 spacers, it is almost impossible to verify the activity of the desiccants since these are an integral part of the spacer, other tests are different from those carried out with the aluminum spacer, as reported in the System Description and verified with third-party ITT tests.

2) For Group 2 spacers, the tests regarding air vent permeability, outer sealant adhesion, quantity of desiccants used, application of the butyl, etc., are problematic and the results obtained are different from those found with the aluminum spacer, as reported in the System Description and verified with third-party ITT tests.

3) No problem arises with the use of Group 3 spacers.

5) CONFORMITY WITH THE STANDARDS, PARTICULARLY UNI EN 1279

The CE Marking is required by law, and failure to comply with this obligation leads to legal repercussions. In addition to the initial ITT controls, the factory controls provided for by UNI EN 1279/6 are also mandatory and must be carried out daily by every insulating glass unit manufacturer.

Currently only the steel spacer fully satisfies the parameters required by the regulations. With regard to the spacers belonging to Groups 1 and 2, the UNI EN 1279/5 currently in force does not “appreciate” the unique characteristics of these new materials which have such critical points as to challenge the validity of an initial tests certificate, the starting point for the CE Marking, obtained with the “classic” aluminum spacer. Furthermore, some properties are difficult to verify and some tests are unreliable (volatile content, adhesion to the spacer, etc.), therefore:

The Group 1 spacers, in order to be used by the Insulating Glass Unit manufacturer in compliance with the CE Marking, require the repetition and passing of all the initial tests, i.e., the tests:

- UNI EN 1279/2 (Moisture Penetration)
- UNI EN 1279/3 (Gas Leakage Rate)

The tests are made mandatory by regulation UNI EN 1279, due to the lack of sufficient data from the use of spacer materials other than inorganic, thus the previous tests carried out on the system with these spacers are not valid for those in plastic.

The Group 2 spacers, in order to be used by the Insulating Glass Unit manufacturer in compliance with the CE Marking, require:

1) Repeating the initial Tests for moisture penetration resistance and gas leakage by the Spacer Manufacturers (UNI EN 1279 2/3)
2) Repeating the initial Tests for moisture penetration resistance and gas leakage by the Insulating Glass Unit Manufacturers to demonstrate the capability to use them correctly (UNI EN 1279 2/3)

The standard would allow a *subjudice* marking in the presence of a report on the prototypes, confirmed by a short test, but exclusively for gas-free glass units.

In both cases the production controls that are carried out on the spacers have to be reconfirmed.

The Group 3 spacers do not require any additional tests with respect to those already carried out with the aluminum spacers, since the System Description remains unchanged for the other parameters.

6) MOISTURE PENETRATION AND GAS LEAKAGE

These are critical factors for spacers belonging to Group 1 and partially for Group 2 spacers. Third-party tests have demonstrated that the moisture and gas barrier is more deficient, especially for the Group 1 silicone spacers.

Excellent results, on the other hand, have been obtained for Group 3 spacers.

7) THE PSI VALUE AND ENERGY SAVINGS: THE SPACER’S EFFECT ON THE Uw CALCULATION

When choosing the spacer to use, the service life of the window is certainly a priority factor. Despite the fact that there may be advantages and regulations that still allow for solutions with

limited service life, this aspect is bound to become increasingly important since it is directly related to customer satisfaction and environmental protection.
The warm edge spacers have Psi (È) values varying from 0.051 to 0.034 depending on the specific construction of the window, with a maximum difference of 0.017. Studies carried out at the IFT German Certification Institute in Rosenheim have demonstrated that, practically speaking, differences of 0.005 offer no substantial benefit. In general, the calculation programs used for the Psi value have an accuracy of +/- 0.003.

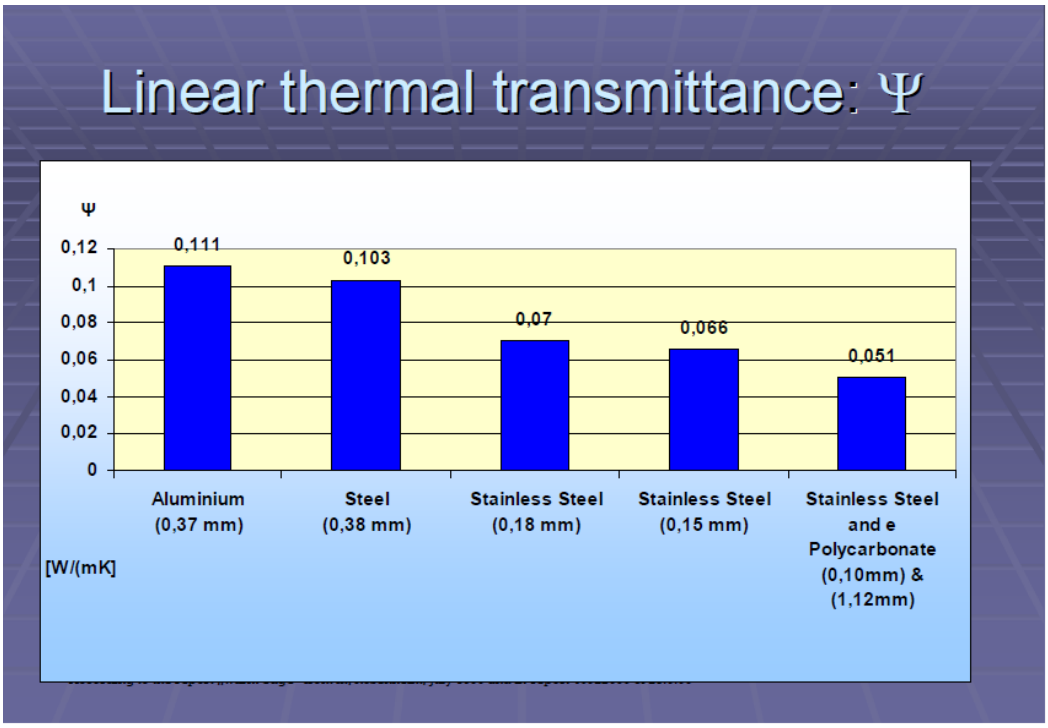
What effect does the Psi value have on the window's U_w value?

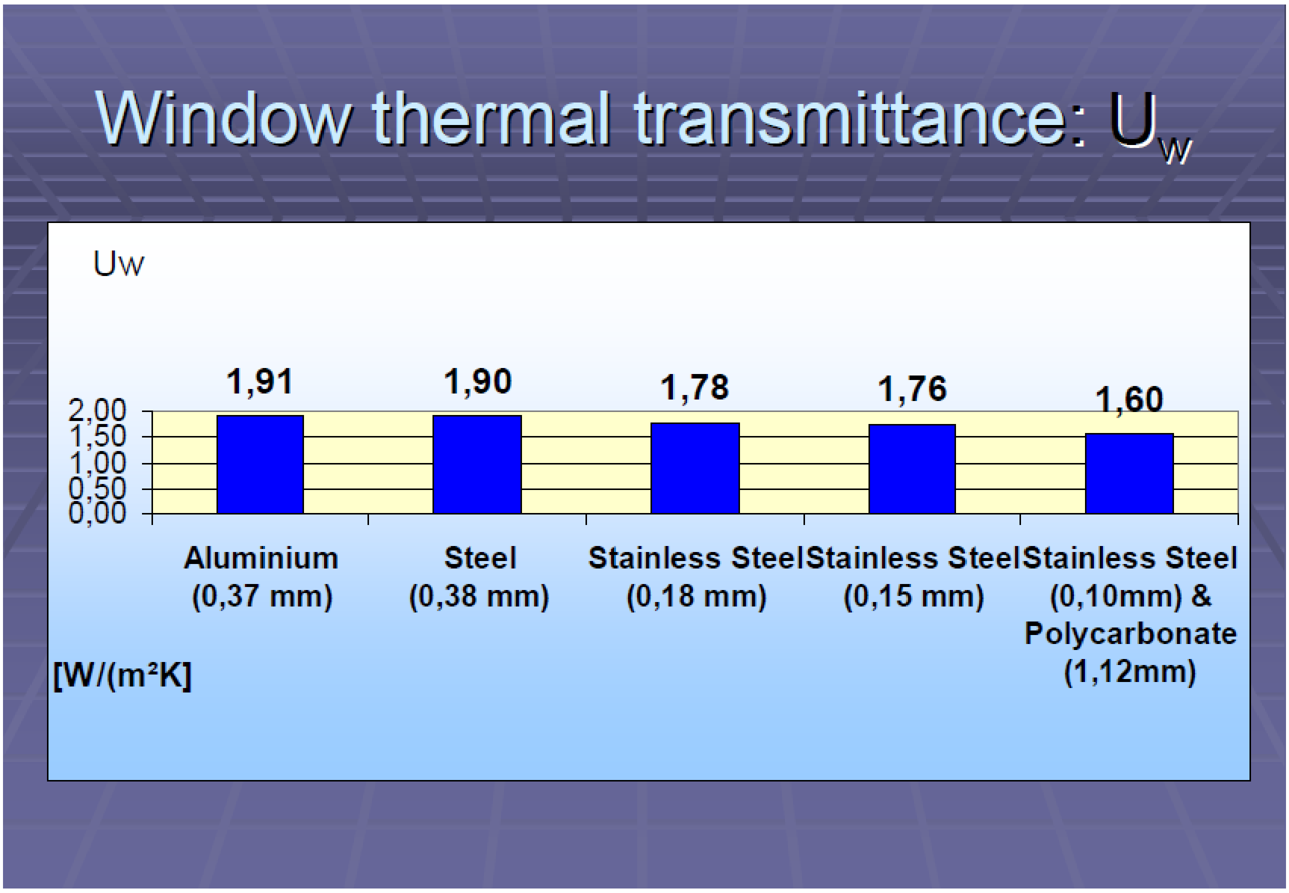
Example: Frame with U_f 1.2 – Insulating Glass Unit with U_g 1.1 (940 x 1048 mm)

Spacer type	PSI [W/m K]	Exact Uw Value [W/m² K]	Rounded value acc. to EN 10077
Aluminum	**0.085**	**1.368**	**1.4**
Stainless Steel 0.15	**0.050**	**1.270**	**1.3**
Extruded PP with Ferritic Steel foil	**0.044**	**1.254**	**1.3**
Extruded PC hybrid spacer with austenitic Steel foil	**0.041**	**1.245**	**1.2**
Flexible silicone	**0.035**	**1.229**	**1.2**

Table 1

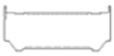
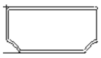
This table clearly demonstrates how small the differences are between the various warm edge systems in terms of performance. **Thus, these values should not be the only selection criteria when it comes to making the right choice.**




Window thermal transmittance: Uw
Uw
1,91
1,90
1,78
1,76
1,60
2,00
1,50
1,00
0,50
0,00
Aluminium (0,37 mm)
Steel (0,38 mm)
Stainless Steel (0,18 mm)
Stainless Steel (0,15 mm)
Stainless Steel (0,10mm) & Polycarbonate (1,12mm)
[W/(m²K]

„Warm Edge“ spacer bars

ROLLTECH A/S - an Alu-Pro Group Company

Spacer	**CHROMATECH plus**	**CHROMATECH**	**CHROMATECH ultra**	**Swissspacer**	**TGI**	**Thermix TXN**	**SS Triseal**	**TPS**
								
Supplier	**Rolltech**	**Rolltech**	**Rolltech**	**Saint Gobain**	**Technoform**	**Ensinger**	**Edgetech**	**Various Sealant Supplier**
Spacer bar system	**Homogeneous Stainless steel**	**Homogeneous Stainless steel**	**Stainless steel with PC bridge**	**Composit - plastic**	**Composit - plastic**	**Composit - plastic**	**Silicone foam**	**Thermoplastic**
Insulating Material	SST 0,15 mm	SST 0,18 mm	Polycarbonate	Polycarbonate / fibreglass	Polypropylene	Polypropylene / fibreglass armed	Silicone with desiccant implemented	Isobutylen / desiccant
Damp barrier	SST 0,15 mm	SST 0,18 mm	SST 0,10 mm	SST 0.01mm / Alum Foil	SST 0,10 mm	SST 0,10 mm	Multilayer plastic spray	Isobutylen
Production technology	Roll forming	Roll forming	roll forming & connect with polycarbonat bridge	Extruded & separate foil application	SST/PP Co-extrusion	SST/PP-fibreglass co-extrusion	Extruded; separate Foil & Acrylic glue application	Lenhardt Robot application from drums
PSI value W/mK PVC frame	**0,051**	**0,051**	**0,041**	**0,034 - 0,045**	**0,044**	**0,041**	**0,035**	**0,039**
Remarks	Corrugated austenitic SST profile	Traditional austenitic SST standard profile	Austenitic SST shell & PC Top	Variations with different damp barrier foils & diff. Psi values	Ferritic steel & PP	PP Fiberglas & Glued Moisture barrier	Triseal with Butyl barrier - diff. Moisture barrier	Thermoplastic spacer

GLASS ALLIANCE

Summary Table: Comparison With The Aluminum Spacer

Characteristics	Group 1: Type A – flexible butyl spacers (TPS)	Group 1: Type B – flexible silicone spacers	Group 2: Plastic Spacers (Chromatech Ultra, Swisspacer, Thermix TXN, TGI, etc.)	Group 3: Steel Spacers
Composition	Thermoplastic Matrices	Silicone Matrices with Incorporated Molecular Sieves	Extruded PP/PC combined with Metal Foil with barrier function (Moisture/Gas)	Homogeneous Steel
Indicative Psi Values	☺☺☺	☺☺☺	☺☺	☺
Reduction of Energy Consumption	☺☺☺	☺☺☺	☺☺☺	☺☺☺
Reduction of Condensation	☺☺☺	☺☺☺	☺☺☺	☺☺
Surface Temperature of the Glass	☺☺☺	☺☺☺	☺☺☺	☺☺
Lower CO_2 Emissions	☺☺☺	☺☺☺	☺☺☺	☺☺☺
Bendability	☺☺☺	☺☺☺	☺☺	☺☺☺❄
Linear Thermal Expansion	☺	😐	☹	☺☺☺
Mechanical Stability	☺☺	☹	☺	☺☺☺
Compatibility with Edge Sealants	☺☺☺	☹	☺	☺☺☺
Adhesion to Outer Sealant	☹	☹	☺☺	☺☺☺

Characteristics	Group 1: Flexible Spacers (TPS)	Group 1: Type B – flexible silicone spacers	Group 2: Plastic Spacers (Chromatech Ultra, Swisspacer, Thermix TXN, TGI, etc.)	Group 3: Steel Spacers
Ease of Use in Production	☺☺❄	☺❄	☺☺	☺☺☺❄
Production Controls (System Description)	☹	☹	☺☺	☺☺☺
Conformity with UNI EN 1279 2/3 Standards	☺☺	☹	☺☺	☺☺☺
Moisture Penetration and Gas Leakage Resistance	☺☺☺	☹	☺	☺☺☺
Desiccant Filling Capacity and Absorption	☺	☹	☺	☺☺☺

❄ = with adapted machinery

☹ = poor or to be verified

😐 = pass

☺ = good

☺☺ = very good

☺☺☺ = excellent

CONCLUSIONS

The insulating glass unit’s service life is affected by climate, sunlight, exposure to UV radiation, wind, frame movement, altitude differences, etc.

The edge seal must withstand all the effects of these external influences. This seal is ensured by the spacer, inner sealant and outer sealant.

The introduction of warm edge profiles has indeed led to improved thermal performance of insulating glass units, but may increase the criticality of the system.

We have discussed the following critical factors: Mechanical stability, Thermal expansion, Compatibility with the edge sealants, Adhesion to the outer sealant, Use in production, Conformity with the standards, Moisture penetration and gas leakage, È value and energy savings.

There is no Warm Edge spacer profile that simultaneously exhibits excellent behavior in all the critical factors.

Thus the choice of the profile should be weighed based on the intended use, the outlet market of the glass factory, the processing equipment used by the glass factory and its propensity to invest.

The tests carried out have shown that plastic spacers may undergo sufficient expansion to cause defects in the edge seal. Any butyl which may be applied may not actually adhere completely to the glass and the spacer itself.

As regards structural glazing, the much larger size of the insulating glass units leads to growing mechanical stability problems. Furthermore, the almost exclusive use of silicone-based second-barrier sealants reduces the performance in terms of Argon gas retention inside the glass unit. Therefore it becomes essential to use spacer materials which have the lowest thermal expansion possible. In these cases the use of homogeneous stainless steel is certainly advisable.