


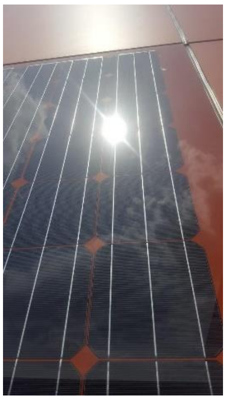

Q-Air – longevity of sealed glass units

Will the gas stay in the sealed compartments, is the question that often comes to mind when dealing with the issues of insulating glass units' longevity?

It will come as a surprise to many, that the loss of argon or krypton gas is not what determines the lifespan of a sealed glass unit. Degradation originates in silver Low-E coating corrosion, which is greatly exacerbated by water vapour migration into the sealed unit. This corrosion determines the primary lifespan of the unit where low U-value should be maintained. Over many years, U-value of such glazing unit will increase to an equilibrium value from which it will increase no more. At this point, some visible artefacts might appear on the glass. Secondary lifespan will commence and will endure until polymer materials degrade to a point where units will start to fail structurally. Insulating glass units provably endure its secondary lifespan for 50 and more years counted from the date of manufacturing.

REFLEX

Q-Air

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The centre of glass U_g value

Heat transfer through the glazed unit consists of heat radiation exchange among the glass panes and gas-gap related heat transfer combining conduction and convection. Q-Air reduces heat transfer using low thermal conductivity gas, which in most applications is argon and through the application of Low-E coatings, which mitigates heat radiation.

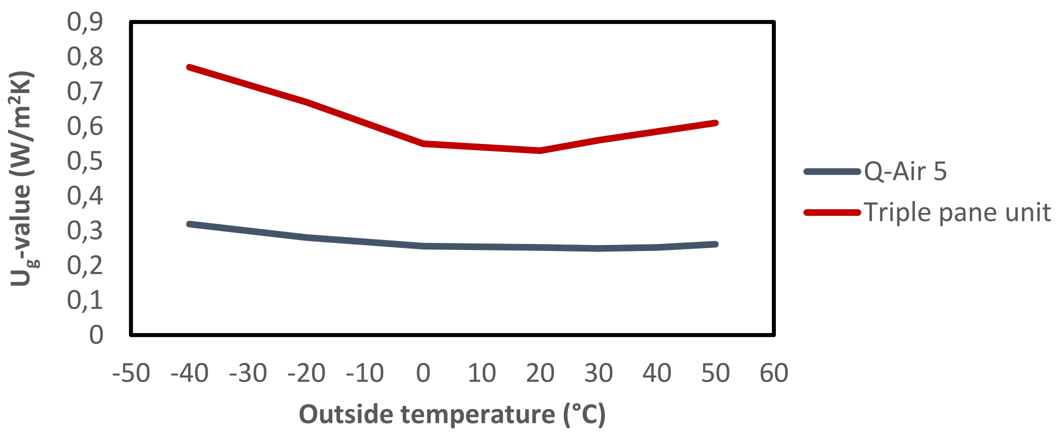
As the glass unit ages, loss of gas and degradation of Low-E coating will gradually increase the U_g value of the glass unit. The calculated table below shows estimated approximate timeline of these changes and their influence on the degradation of the U_g value.

	Expected approximate age in years	Gas concentration	Low-E emissivity	Triple pane unit (TGU) U value [W/m²K]	Six-pane unit (Q-Air5) U value [W/m²K]
Initial U_g value	0	90%	0.034	**0.55**	**0.26**
End of primary lifespan	25	70%	0.036	**0.58**	**0.275**
	U value increase from initial value			0.03	0.015
Loss of Low-E function	35	50%	0.84	**1.68**	**0.85**
	U value increase from initial value			1.13	0.59
Equilibrium with the atmosphere	50	0%	0.88	**1.73**	**0.88**
	U value increase from initial value			1.18	0.62

Argon gas is expected to permeate out of the glass unit at a rate less than 1% annually for the first 25 years (EN 1279). After that, the rate might increase due to aged seals. Sealing systems are checked against argon gas loss within the EN 1279 certification. If krypton gas is used, it will permeate out at considerably lower rate than argon due to its larger atomic size.

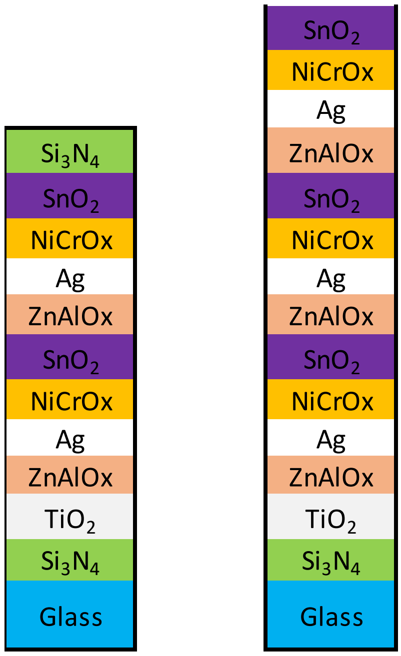
Glass units are designed for a specific primary lifespan, which depends solely on the Low-E coatings survivability. As can be seen from the table above, the effect of gas-loss is only secondary to the loss of Low-E functionality, which will be dealt with separately in this brochure.

Sealed glass units' centre of glass U value (U_g) also change with exterior conditions. Here is an example of simulated glass deflections for the Q-Air 5 and triple pane unit:



Corrosion of the silver Low-E coating

Low-E, as the name suggests, is a coating with low emissivity for heat radiation. It prevents heat exchange among glass panes in the insulating glass unit. It behaves as a heat mirror reflecting light in the thermal infrared range of wavelengths from 3 to 50 µm. In the case Low-E glass is simultaneously a sun-control glass it is optimized for reflection from 0.8 to 50 µm.



Double silver **Triple silver**

Modern Low-E and sun-control coatings are double and triple silver layer "stacks" as shown in the right image. Thin silver offers unmatched transparency in the visible range of electromagnetic spectrum. Unfortunately, silver corrodes[1] in the presence of water. Water vapour migrates to the silver substrate layers and disintegrates the adhesion of silver. This is in large part due to silver's inability to bond chemically to other substrates. Silver is a "noble" metal for its renowned inertness.

Silver is vacuum sputtered over a prepared substrate to which it bonds physically through weak electromagnetic interaction. By design, layers below and above the multiple silver layers provide for protection from water vapour ingress, and an appropriate dielectric/semiconductor material for the stack to form proper light interferences to produce the desired light cut-off at the end of the visible or near-infrared ranges.

These Low-E coatings can safely survive exposure to the atmosphere for a couple of days for the duration of the manufacturing process. Some such coatings can even be heat treated as these treatments are done in hot and dry ovens. Somewhat trickier is heat soak testing as the heat soak test requires a period of annealing at a somewhat lower temperature where air humidity might start attacking the silver layers. Therefore, heat soak testing for heat threated Low-E coating is designed as somewhat faster and not quite as efficient as standard heat soak procedure is.

In the patent literature, we may find numerous attempts to design a Low-E coating stack with a metal other than silver that would bind to the substrate chemically. No attempt so far has produced a coating with useful transparency combined with needed high reflectance for the thermal infrared.

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[1] Meszaros, Robert, Michael Wild, and Lothar Wondraczek. "Effects of substrate and long term corrosion on PVD-multilayer coatings for architectural glazing." *Glass Technology-European Journal of Glass Science and Technology Part A* 54, no. 5 (2013): 177-184.

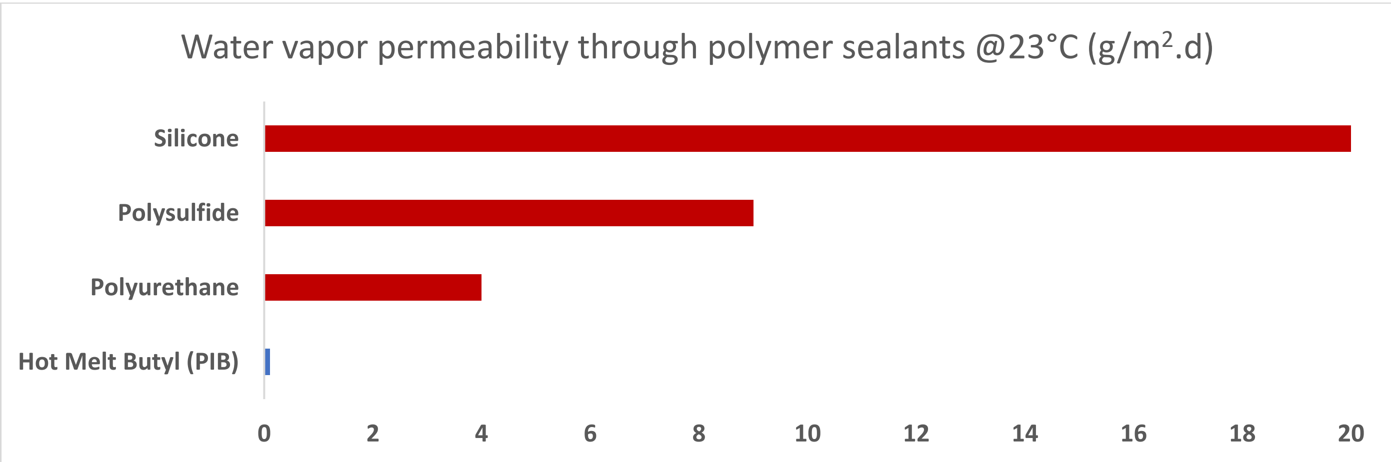
Water vapour ingress

From glazing engineering standpoint, aluminium, stainless steel and float glass are water vapour impermeable. These materials exhibit only trace permeability relevant to high and ultrahigh vacuum applications where even trace quantities must be accounted. Atmospheric water vapour slowly migrates into the sealed insulating glass unit through the polymeric seals where it slowly saturates the desiccant. It is the purpose of desiccant, residing in the spacers to uptake the water as it passes through the sealant. Note, that desiccant does not remove vapour from the glass unit's cavities entirely, it merely keeps it at very low level.

One could now in principle suggest that to lengthen the lifespan of the glass unit one would need only to increase the desiccant quantity appropriately. As trivial as this method might seem, reality, however, denies us this option, because sealant materials age as well.

Tiny, constantly present humidity in the cavities also slowly degrades the Low-E coating as described in the previous chapter. In combination, these effects bring expected lifespan of the insulating glass units into the range that is the same, within the order of magnitude, for all manufactured sealed glass units. If a sealed unit fails before of its expected lifespan, it is usually due to faulty design or manufacturing defect. Manufacturing flaws show visible defects within two to three years of installation in most cases.

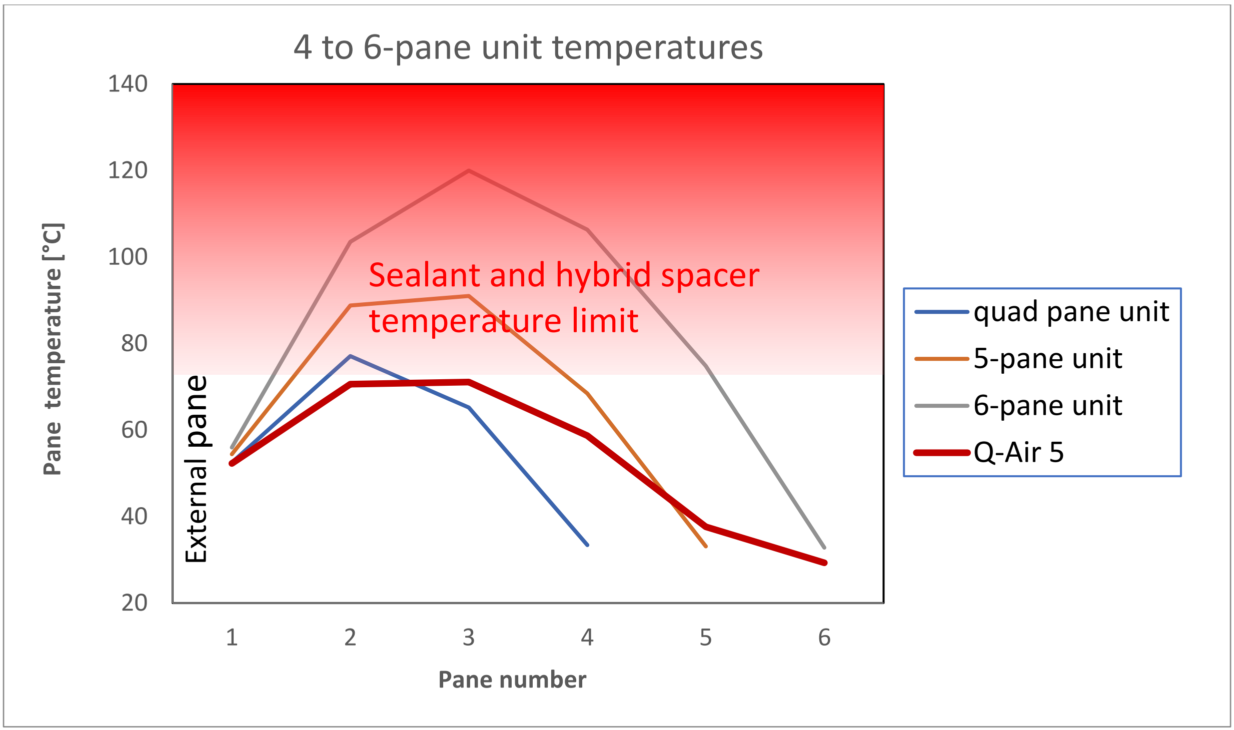
Proper use of polymeric seals is what insulating glass unit's durability is all about[2]. From the chart immediately below, we can see that primary PIB seal is what holds water vapour from migrating into the glass unit.



Purpose of the secondary seal (silicone, polysulfide, polyurethane) is to hold the primary seal in place[2]. Increased summer insulating gas pressure, spacer to glass length variations will stretch the primary PIB seal and thus reduce its effectiveness as water vapour barrier. Viscoelastic mechanical properties of secondary seal play an essential role in assuring the long-lasting effect of Low-E coatings[2].

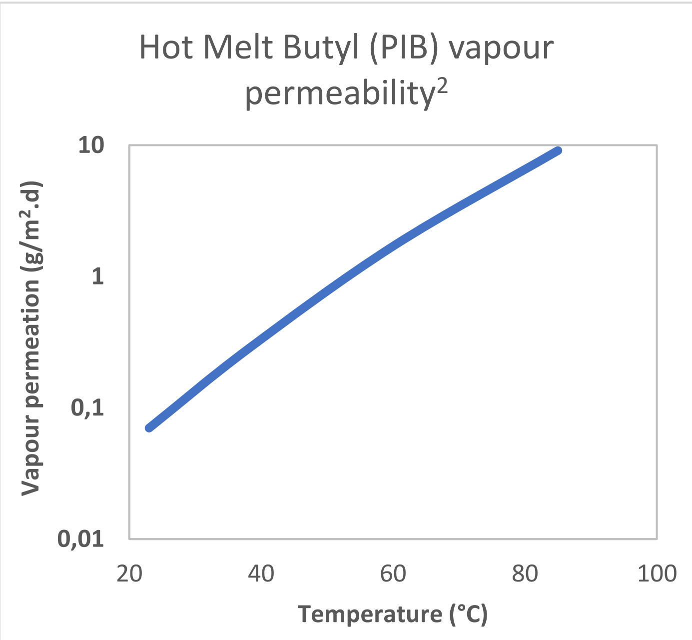
[2] A.T. Wolf, L.J. Waters, Factors governing the life expectancy of dual-sealed insulating glass units, Constr. Build. Mater. 7 (1993) 101–107.
A.T. Wolf, Design and Material Selection Factors That Influence the Service-Life and Utility Value of Dual-Sealed Insulating Glass Units, 9DBMC-2002 Paper. Dow Corning SA, 2002.

This would be the end of story if we were talking about double-pane glass units. In the multipane glass configurations, however, there is always at least one glass pane that is out of contact with the exterior. In the summer sun those middle panes heat-up considerably.



In the diagram above temperatures of individual glass panes in contact with the primary seal are shown for various unsophisticated multipane glass arrangements and the Q-Air as reference.

Q-Air uses two approaches to protect the temperatures of intermediate panes from rising. First, solar control glass must always be used, second, glasses are selected in such a way that there are minimal absorptions of the remaining visible light.



PIB primary seal increases vapour permeability with the temperature a lot (left image)[3]; more than a hundred-fold from room temperature to 80°C. It is of paramount importance for the multipane glass unit longevity to always keep middle glass pane's temperatures at below of 70°C. This keeps PIB permeability at less than 1.5 g/m^2d which is upper design value for the insulating glass[4].

Of course, overall absorbed humidity depends on local factors such as the local climate's summer heat and humidity and side of the building on which the glass unit is and especially on the colour of spacers. Dark spacers can negatively impart multipane glass-unit longevity.

[3] ASTM F 1249, 1 mm film, 100% relative humidity.
[4] Amstock, Joseph S., "Sealant Selection," Glass Magazine, July 1990.

Expected average primary lifespan comparisons

As already indicated above, the exact lifespan of a glass unit is a mixture of climatic, engineering design and manufacturing quality parameters. With multipane glazing, it is the management of insolated primary seal that is less known and usually neglected by suppliers of novel triple and quadruple glass units. The EN 1279 certificate is meaningless in this respect as it tests for double glazing temperature conditions. In the table below are given expected primary life-spans of well-engineered glass units. **Note that primary lifespan does not mean that upon its expiry there will be immediately noticeable performance losses.** One should look at the primary lifespan much like as the “best before” note on food stickers.

	Desiccant quantity (spacer width - mm)	Summer seal temperature (°C)	Primary lifespan (years)
Single glazing	-	-	50
Uncoated double glazing	-	-	50
Modern coated double glazing	16	45	30
Modern coated triple glazing	14	55	25
Modern coated quadruple glazing	12	70	20
Six-pane Q-Air 5 glazing	18	60	25

There are some clear warning signs that engineers have overlooked the dangers of overheated primary seal:

- use of dark spacers,
- use of chromogenic (electrochromic) solution with multipane glass unit,
- use of heat strengthened or toughened inner glass panes.

Heat treated inner glass panes indicate that engineers are aware that these panes will experience exploitation temperatures 80°C or above.