Gas Space Convection Effects on U-values Of Insulating Glass Units

Logical thinking might lead us to believe that increasing the gas space width, the distance between the interior surfaces of glass lites, in an insulating glass unit (IGU) will always improve the IGU's insulating value. We would be wrong to jump to that conclusion. Actually, gas space width and gas fill type, both influence the insulating value (U-value) of an IGU.

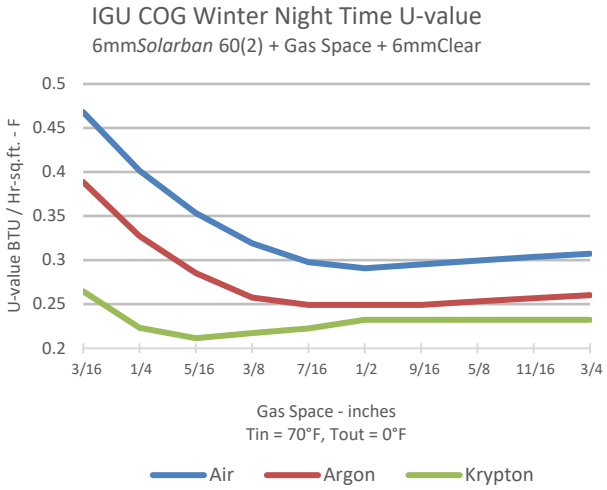
There are three gas types that are commonly used in IGU today. They are ambient air, argon, and krypton. Of course they vary in cost and in physical properties. Air is free, argon is relatively low in cost, and krypton is considered expensive.

Gas Space Width

Although important, gas space width alone does not determine the insulating value of an IGU. For each of the three common gases named above, there is an optimum gas space width at which they each perform best (see table).

Gas Fill Type	Optimum Gas Space Width (inches)	Center of glass U-value at Optimum Gas Space Width (btu/hr-ft-°F)
Air	1/2 (.500)	0.31
Argon	7/16 (.438)	0.26
Krypton	5/16 (.313)	0.23

The following graph shows what actually happens to the center of glass U-value of an IGU filled with various gas types and constructed with *Solarban®* 60 Solar Control Low-e Glass outboard lite, and clear glass inboard lite.



You can see that as the gas space goes from a very narrow width (3/16") to the optimum widths for air and argon (around 1/2"), the U-value drops dramatically.

Remember that lower U-value means a slower rate of heat flow through the IGU.

U-value then levels off for a bit. As the gas space width increases further, the U-value actually increases or gets worse. The optimum values are not the same for all of the gas types. The optimum gas space width is widest for air, slightly smaller for argon, and smallest for krypton. So, with krypton gas fill, you can make thinner IGU's and achieve better insulating values than with argon filled or air filled units.

Gas Fill Type

So why do different gases react differently in IGU's and why does U-value get worse if you increase the gas space width beyond the optimum width? There are two factors involved: a) thermal conductivity of the gas and b) density of the gas. Air, argon, and krypton each have different thermal conductivities and densities as shown in the following table.

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Gas Fill Type	Thermal Conductivity (btu/hr-ft-°F)	Gas Density at 32°F (lbs/cu.ft.)
Air	0.0139	0.0805
Argon	0.0094	0.111
Krypton	0.0050	0.2335

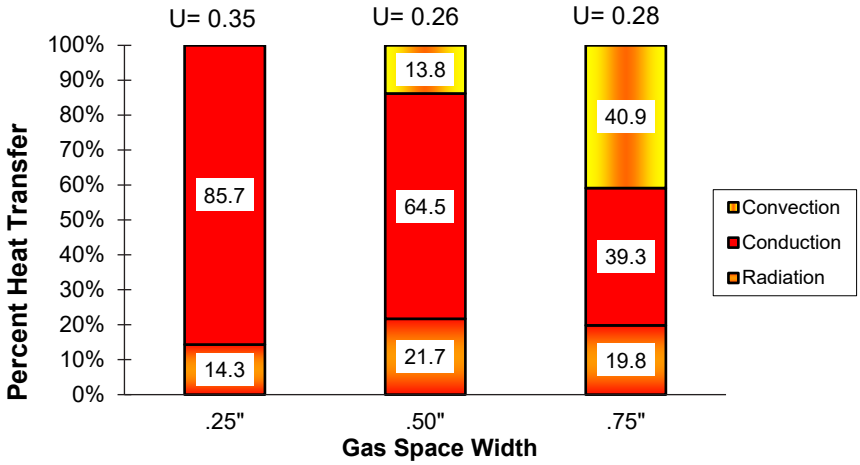
If free convection did not occur, then thermal conductivity alone would control the heat flow through an IGU and you could continue to make the gas space width larger and larger to increase the insulating value of the unit. However, free convection does occur within the gas space of an IGU. This free convection is caused by temperature differences between the indoor glass and the outdoor glass of the IGU. In winter, the outdoor glass is usually colder than the indoor glass. In summer, inside air-conditioned buildings and houses, the outdoor glass is usually warmer than the indoor glass. The gas adjacent to the warm glass rises, and the gas adjacent to the cold glass falls. While the gas in the center of the space becomes stagnant and is bypassed by the rising and falling gas near the glass surfaces. This results in a continuous circular movement of the gas within the inner space of the IGU. This free convection gas movement transfers heat from the warm glass to the cold glass in addition to the heat which is transferred by conduction. As a result, the convection heat transfer counteracts the conduction heat transfer and the larger the gas space the greater this affects the insulating value of the IGU.

However, keep in mind that the gas at the inside and outside lites must overcome the viscous resistance of the gas at the center as well as the viscous resistance to motion at the glass surfaces for convection to occur. Since krypton and argon have higher densities than air, it is more difficult for convection to start.

How much does free convection affect heat transfer?

Here is an example:

A comparison of the heat transfer for three different IGU gas space widths – 1/4", 1/2" and 3/4" is shown in the following chart. The chart breaks down the components of heat transfer, convection, conduction, and radiation and shows how they are different for each different gas space width. All the IGU's are argon filled and have a low-e outside lite.



Percent Heat Transfer from Radiation, Conduction, and Convection
Double Glazed Unit w/ one lite of low-e glass and argon gas fill

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For the 1/4" gas space, the difference in temperature between the two lites is less and the buoyant force acting on the fill gas is not sufficient to overcome the viscous or frictional resistance of the gas. Therefore, convective heat transfer is zero while conduction and radiation account for 85.7% and 14.3% respectively and the center of glass U-value is 0.35 btu/hr-sqft-°F.

However, as the gas space is increased in width to 1/2", the temperature difference between the two lites increases and the buoyant forces become larger relative to the frictional resistance to gas motion. In this case, the convective heat transfer accounts for 13.8% while conduction and radiation account for 64.5% and 21.7% respectively with the center of glass U-value reduced to 0.26 btu/hr-sqft-°F.

When the gas space is increased to 3/4", the temperature differences between the two lites increases even more, as do the buoyant forces relative to frictional resistance. In this case the convective heat transfer accounts for 40.9% while conduction and radiation account for 39.3% and 19.8% respectively. This results in a U-value of 0.28 btu/hr-sqft-°F which is larger than that for the 1/2" gas space. So you can see from this example, that increasing the gas space at first reduced the overall heat transfer. But when the gas space is increased further, the heat transfer actually increases because of the increased argon circulation and convection effects.

Glass Emissivity

Low-e glass is glass that has been treated with a low emissivity coating on one or more surfaces. Emissivity is defined as the ratio of the energy radiated from a material's surface to that radiated from a perfect emitter, known as a blackbody, at the same temperature and wavelength and under the same conditions. Stated another way, a material's emissivity determines the amount of thermal radiation emitted from its surface. It is a dimensionless number between 0 (for a perfect reflector) and 1 (for a perfect emitter). The following table has emissivity and center of glass U-values for various Vitro glass products. Generally, the lower the emissivity the better the center of glass U-value will be as more thermal radiation is reflected away.

Glass Type	Emissivity (low-e)	U-Value* (air)	U-Value* (argon)
Clear	0.840	0.47	0.45
Sungate® 400	0.113	0.32	0.28
Solarban 60	0.035	0.29	0.24
Solarban 70	0.018	0.28	0.24
Solarban 72	0.018	0.28	0.24
Solarban 90	0.023	0.29	0.24
Solarban R67	0.035	0.29	0.24
Solarban R77	0.025	0.29	0.24
Solarban R100	0.036	0.29	0.25

* U-value (center of glass; winter night) based on 1" double glazed unit with 6mm outboard lite of the glass type listed and 6mm clear inboard lite

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Conclusions

1. Gas fill improves the insulating value of IGU's compared to air filled units.

2. Gas fill helps control free convection due to the increased density of the gas compared to air. This results in less heat transfer through the IGU.

3. Using the optimum gas space width for a specific gas type acts to control free convection while realizing the benefits of the lower thermal conductivity of the specific gas type.

4. There is an optimum gas space width for each gas type which will generate an optimum insulating value. If the gas space width is less than or greater than the optimum width, the U-value of the IGU is compromised.

HISTORY TABLE		
ITEM	DATE	DESCRIPTION
Original Publication	5/10/1995	
Revision #1	11/27/2001	Revised & transferred to TD-101
Revision #2	10/04/2016	Updated to Vitro Logo & format
Revision #3	1/18/2019	Updated the Vitro Logo & format
Revision #4	7/26/2023	Updated to replace Sungate w/ Solarban 60; Clarified U-value is center of glass; Added table w/ emissivity & U-values