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

Instinct and common sense might lead us to believe that increasing the gas space width in an IG unit will always improve the IG unit'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 IG unit.

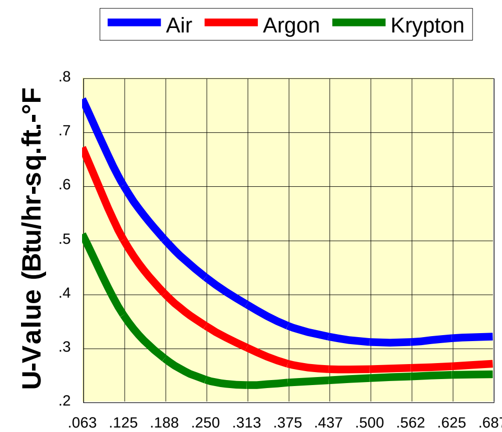
There are three gas types that are commonly used in IG units today. They are air, argon, and krypton. Others are used occasionally, but air, argon, and krypton are the most common. Of course they vary in cost and in other properties. Air is free, argon is relatively low in cost, and krypton is considered expensive.

Gas Space Width

Gas space width alone does not determine the insulating value of an IG unit. But it is important. For each of the three common gases named above, there is an optimum gas space width, at which they each perform best. The table below shows those values.

Gas Fill Type	Optimum Gas Space Width (inches)	U-value at Optimum Gas Space Width (btu/hr-ft-°F)
Air	1/2 (.500)	.31
Argon	7/16 (.438)	.26
Krypton	5/16 (.313)	.23

The graph below shows what actually happens to the insulating value or U-value of an IG unit with various gas types with a clear glass outdoor lite, and SUNGATE 100 low-e coating on the 3rd surface of the IG unit.



You can see that as the gas space goes from a very narrow width (.063") to the optimum widths for air, argon, and krypton, the U-value drops dramatically.

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

U-value then levels off for a bit. Then as gas space width increases, the U-value increases or gets slightly worse. And 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. Another way to say this is, with krypton gas fill, you can make thinner IG units and achieve better insulating values than with argon filled or air filled units.

Gas Fill Type

So why do different gases react differently in IG units and why does U-value get worse if you increase the gas space width beyond the optimum width? There are two factors. They are thermal conductivity of the gas and density of the gas. Air, argon, and krypton each have different thermal conductivities and densities. See the table below.

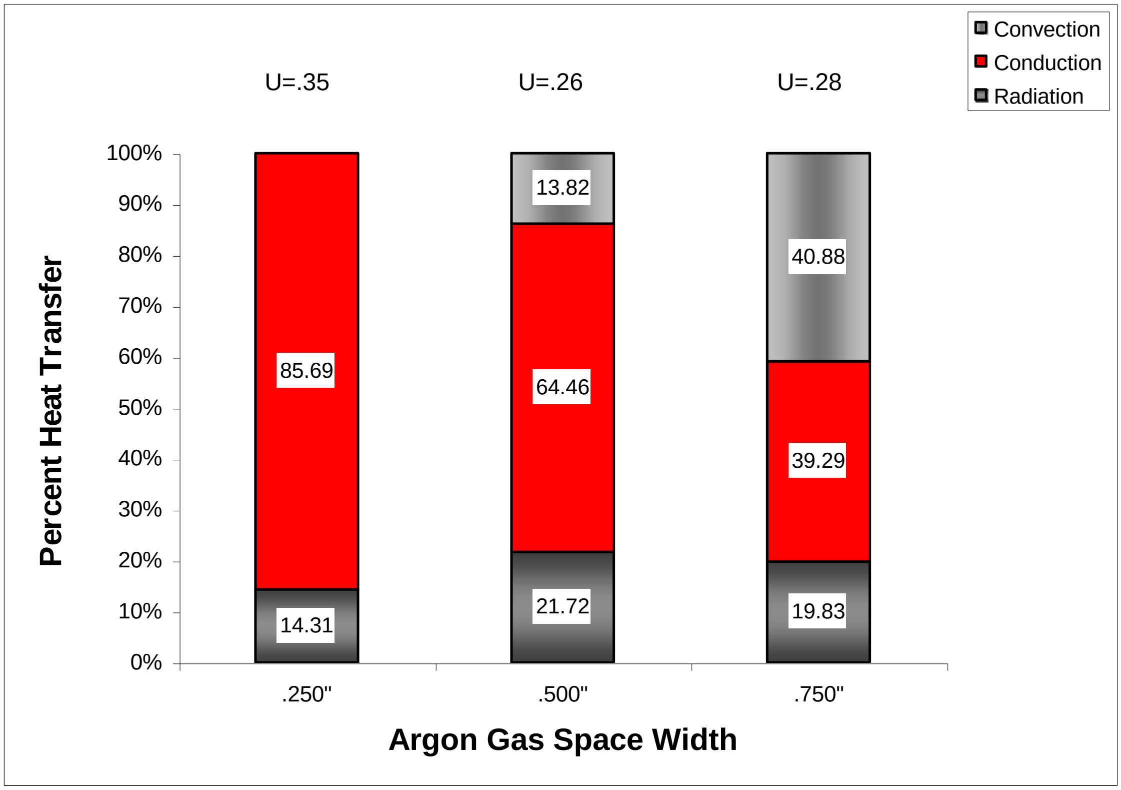
Gas Fill Type	Thermal Conductivity (btu/hr-ft-°F)	Gas Density at 32°F (lbs/cu.ft.)
Air	.0139	.0805
Argon	.0094	.111
Krypton	.0050	.2335

If free convection did not occur, then thermal conductivity alone would control the heat flow through an IG unit, 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 IG unit. This free convection is caused by temperature differences between the indoor glass and the outdoor glass of the IG unit. In winter the outdoor glass is usually colder than the indoor glass. In summer, in 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 sinks, while the gas in the center of the gas space becomes stagnant and is bypassed by the rising and sinking gas near the glass surfaces. This results in a continuous circular movement of gas within the gas space of the IG unit. This free convection gas movement transfers heat from the warm glass to the cold glass in addition to that which would be transferred by conduction alone. This counteracts the insulating effect of a larger gas space.

However, keep in mind that the gas at the inside and outside lights 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 begin.

How much does free convection affect heat transfer?

Here is an example. A comparison of the heat transfer for three different IG unit gas space widths, 1/4", 1/2" and 3/4", is shown in the chart below. 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 of the IG units are argon filled and have one lite of low-e.



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

For the 1/4" gas space, the difference in temperature between the two lights is less and the buoyant force acting on the fill gas is not sufficient to overcome the viscous resistance, or frictional resistance of the gas. Therefore, the convective heat transfer is zero, while conduction and radiation account for 85.69% and 14.31%, respectively, and the U-value is .35 btu/hr-sq.ft.-°F.

However, as the gas space is increased in width to 1/2", the temperature difference between the two lights increases, and the buoyant forces become larger relative to the frictional resistance to gas motion, or free convection. In this case, the convective heat transfer accounts for 13.82% while conduction and radiation account for 64.46% and 21.72%, respectively, with the U-value reduced to .26 btu/hr-sq.ft.-°F.

If the gas space is increased to 3/4", the temperature differences between the two lights increases even more, as do the buoyant forces relative to frictional resistance. Here, the convective heat transfer accounts for 40.88% while conduction and radiation account for 39.29% and 19.83%, respectively, resulting in a U-value of .28 btu/hr-sq.ft.-°F, which is larger than that for the 1/2" gas space. So, you can see from this, that increasing the gas space at first reduced the overall heat transfer, but when continued, actually increased heat transfer because of the increased argon circulation or convection.

Conclusion

So, what can we conclude from all of this?

1. Gas fill improves the insulating value of IG units.
2. The denser gases help control free convection.
3. There is an optimum gas space width for each gas type, which will generate an optimum insulating value.
4. Using the optimum gas space width for a specific gas type, acts to control free convection, while realizing the benefits of the lower conductivity of the specific gas type.

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HISTORY TABLE		
ITEM	DATE	DESCRIPTION
Original Publication	5/10/1995	
Revision #1	11/27/2001	Revised & transferred to TD-101
Revision #2	2016-10-04	Updated to Vitro Logo and format