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IGUMA - IGU Design Limitations

Introduction

Insulating Glass Units (IGU's) are being used more frequently in domestic and commercial buildings to provide improved insulation, comfort, condensation and noise control. However, specifier's need to understand the principles of IGU's and the limitations these place on design.

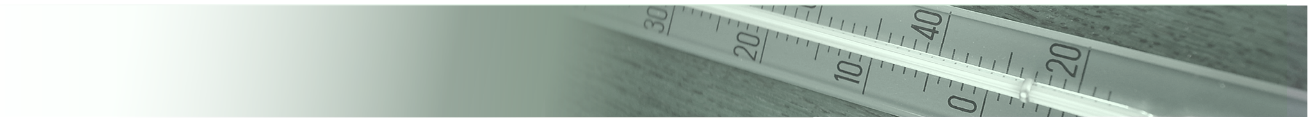
The Basics

Clear monolithic glass accounts for less than 5% of a windows insulation value, the rest being supplied by the still air layers of the environment on either side of the glass. Since the heat flow resistance of still air is much greater than that of glass, a glass unit made of two panes enclosing an air space will have about twice the insulation value of a single pane window (half the heat loss). Triple pane units with two sealed airspaces have an insulating value approximately three times that of single glazing.

This is why double and triple glazed units are called Insulating Glass Units as they provide insulation to the windows of a building, like fibreglass Insulation provides insulation to the wall.

Insulation

Insulation is measured by the U Value or R Value. The U Value is a measure of the rate of heat loss per square metre of glass for a temperature difference of 1 degree Celsius between the interior and exterior ($W/m^{2o}C$). The lower the U Value the better the insulation.
The R Value is the reciprocal of the U Value (R=1/U), measured in $m^{2o}C/W$, so the higher the R Value the better the insulation. R Values are used more commonly now since the introduction of energy efficiency requirements and the use of NZS 4218:2009.Thermal Insulation – Housing and Small Buildings. This latest version introduces a new term Rwindow for the construction R Value of a complete window including the frame, however this should not be confused with the centre of glass R Value (Rcog) which is for the glass only.



Pressure & Temperature Effects

An IGU is made by sealing air or gas between panes of glass hence the name sealed IGU or SIGU. When the unit is sealed, the initial pressure and temperature of the trapped air are the same as outside the unit. If the panes do not deflect under their own weight, they will initially be flat since there is no difference in pressure acting on them.

As long as the unit remains sealed, the mass of the air between the panes is constant and according to Charles Law, the product of its volume and pressure, divided by its absolute temperature, is also constant. If all the boundaries of the air space were perfectly rigid the volume would be constant too, and changes in pressure outside the unit would have no effect on the pressure inside the unit. But the thin glass panes of an IGU are flexible, meaning that they will deflect if there is a difference in pressure from one side to the other. Hence an IGU can be considered as a sealed flexible chamber.

If the pressure outside the unit increases while the temperature remains the same, the difference in pressure differential will cause the glass panes to deflect inward, thus decreasing the volume of trapped air. If the pressure outside the unit decreases, the pressure differential will deflect the glass outward increasing the volume of trapped air. This is why, for special applications such as high altitude windows, it is important to consider the air pressure at the time of sealing and the air pressure at the glazing location.

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There are five common causes of either positive or negative pressure changes that affect the unit -

1 The barometric changes of weather conditions
2 The barometric effects of a change in altitude between the manufacturing site and the installation site
3 Wind effects
4 Outdoor and indoor air density differences at different temperatures
5 Operations of HVAC system in the building

Temperature changes also result in pressure and volume changes with an increase in temperature causing outward movement of the panes and a decrease in temperature causing inward movement. The change in pressure induced by a temperature rise of 2.7 degrees C is about the same as that caused by a barometric drop of 1 kPa.

The barometric pressure is 101.3 kPa at sea level and it will drop by about 1kPa per 100m in elevation or altitude. This is why special care must be taken for units glazed at high altitude and often pressure equalization is required once in location or by using pressure valves or capillary tubes.

The net result is that an installed IGU is forever deflecting in and out with the changes in climate. This deflection puts stress on the edge seals, which can shorten their life if excessive. This deflection can also create changes in the appearance of transmission and reflection images especially if the units are made from tinted or reflected glass.

If the unit is large and/or square in geometry the airspace may not be wide enough to stop the two panes deflecting in and touching and if they do you get an effect called "Newton's Rings". This also means the glass is no longer insulating as the panes are touching and in some cases the glass surfaces can rub and cause permanent surface damage inside the unit.

The deflections in the unit from changes in temperature and pressure can be calculated. For example a 2500 x 1500mm unit 6/12/6 made on a low pressure day (950mbar) in a factory at 15 C will deflect inward overnight at 10 C on a higher pressure day (1000mbar) by 2mm reducing the airspace to 10mm in the centre.

Wind Pressure Effects

The windows of a building must be strong enough to withstand the effects of wind without breakage. The wind pressure may be positive or negative on a window, depending on its location, height and the orientation of the building surface to the wind and this is known as the pressure coefficient. The wind action also affects the barometric pressure inside the building.

When the outer pane of an IGU is subject to external wind pressure it will deflect inward and the air space acts like a spring forcing the inner pane to do the same. Some spring resistance is lost by the air space and thus the inner pane may not deflect as much as the outer. The actual amount of loss is a complex issue but the new NZS 4223 Part 4:2008 provides load sharing formula (clause 3.4.2) to calculate the individual strength of each pane.

For the wind load design of an IGU, charts are provided in NZS 4223:2008 Part 4, and Tables in Supplement 1, for each glass type once the load sharing of each pane is calculated. For panes of equal thickness the load sharing factor is 0.625. If different glass types and/or thicknesses are used the calculations are more complex and computer software helps. However, as a simple guide it is conservative and safe to consider both panes to be the thinner and weaker of the glass types used. For example, if the units are 5+4 mm annealed glass then use 4+4 from the wind load charts, or tables once the pressure has been reduced by 0.625. The tables provide for both 4 Edge and 2 Edge supported glass and for ULS and SLS wind pressures

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Deflection

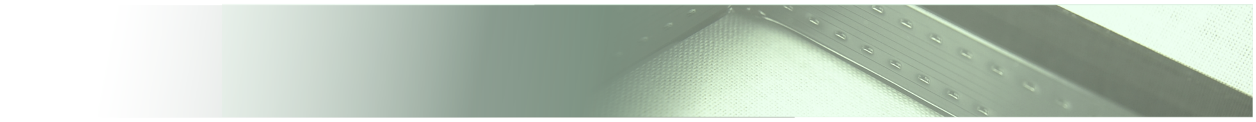
If the panes of the IGU are the same thickness then it is considered that each pane is sharing the wind load due to the spring effect. This is a simplification as the inner pane may be already be deflecting outward (into the building) due to pressure and temperature changes. To calculate wind load deflection the load is shared and each pane calculated according to it thickness.

However, in reality there is a bit of cushioning by the airspace under wind load and the inner pane will deflect a little less, so it is better to have the stiffer glass to the outer pane, if possible but this is not always possible if the outer glass needs to match other windows.
Heat treated glass such as toughened or heat strengthened glass may also have inherent bow or roller wave that can add to the apparent deflection in the unit and it is not advisable to use two large square thin panes of toughened glass in an IGU even if they meet the design load requirements.

Deflection due to wind load is normally limited to 1.5 times the airspace thickness, or 20 mm maximum, otherwise it can become visually disturbing. Table 1 has been prepared using these limits as they have been found to provide units with good service performance and history. (For example 1.5 x 12mm air space = 18mm max.).

It is always advisable to have a large airspace for large units as the deflection due to pressure change can reduce performance and cause Newton's Rings.

Note:
Deflection limits on the glass are based on the frame being stiff enough to support the IGU and frames should comply with NZS 4211 or similar. Any undue deflection in the frame can also increase stress in the edge seals and reduce unit life.



Human Impact

If used in a human impact situations, such as a door, where the unit may be subject to human impact from both sides, then both panes are required to comply with NZS 4223:Part 3:1999. If the unit is subject to human impact from one side only, such as low level glazing in the 1st floor of a building façade, then only the impact side needs to conform to Part 3. This standard allows a 1.5 area factor for IGU's under human impact, refer Clause 303.6.

The table below provides the maximum IGU areas (m2) of different glass types from
NZS 4223:Part 3:1999

Glass	*Toughened*	*Laminated*	*Annealed Column 1*	*Annealed Column 2*	*Annealed Column 3*
4+4	*3*	*NA*	*0.3*	*0.45*	*1.65*
5+5	*4.5*	*3*	*0.75*	*1.8*	*3.3*
6+6	*6*	*4.5*	*1.35*	*3.15*	*4.95*
8+8	*9*	*7.5*	*2.7*	*4.8*	*6.75*
10+10	*12*	*10.5*	*4.05*	*6.6*	*9*
12+12	*15*	*13.5*	*6.75*	*9.45*	*12*

For units with different thickness use the thinner of the two in the above table
E.g. for 5+4 use the 4+4 row

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- Maximum Sizes

Unit weight, handling and glazing implications of a large IGU can often create limitations on the size of the units available. Table 1 gives the normal recommended maximum sizes for vertically glazed IGU's

The max glass size and/or weight can also be restricted by individual manufacturing plants and processes so it is always advisable to check with the supplier. As a guide units should not be over 250kg, otherwise special manufacturing, handling and glazing equipment may be required.

To calculate the approximate weight use the following

Height (m) x Width (m) x 2.6 kg/m2 x [thickness outer (mm) + thickness inner (mm)}
e.g. For a 2m x 1m, 6/12/6 unit = 2x1x2.6x(6+6) = 62.4 kg

Handling and glazing large heavy IGU's is best done with strops so both panes are supported but in some cases suckers are required. If suckers are used on one side only they can put shear stress on the IGU seals and damage them.

Note:
The thickness and weight of large IGU's can also put severe restrictions on the type of joinery, especially in the case of sliding and pivot doors. In some sash windows special stays and hardware are required to hold the windows open.

- Manufacturing Facilities

GANZ members have a range of manufacturing facilities in NZ and maximum sizes will vary according to the process and equipment. As a guide the standard maximum size for air and argon filled units is 4000 x 2500mm. In some cases larger units can be made by hand.

Spacer widths also vary but standard aluminium spacer widths are normally 6,8,10,12,14,16, and 18 mm and available in silver and black.

Special warm edge spacers, with high performance stainless steel and engineering plastic are also available in black and widths 8, 10, 12, 14, 16, & 18 mm.

Super Spacer silicone foam warm edge technology units and spacer widths are metric nominal 6, 8,10,11,12 &14mm (Actual 6.35, 7.94, 9.52,11.11,12.7,14.29mm)

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Table 1

		Wind Zones (NZS 4223:Part 4:2008)							
		Low	0.72 kPa ULS 0.51kPa SLS	Medium	0.96 kPa ULS 0.68 kPa SLS	High	1.36 kPa ULS 0.97 kPa SLS	Very High	1.76 kPa ULS 1.25 kPa SLS
IGU Makeup	Spacer Width	Max. Short	Max. Long	Max. Short	Max. Long	Max. Short	Max. Long	Max. Short	Max. Long
4 + 4	6mm	1050	2200	1050	1800	900	1900	850	1750
4 + 4	8mm	1200	2300	1150	2100	1000	2100	1000	1750
4 + 4	10mm	**1350**	**2500**	**1350**	2150	1100	2300	1100	1950
4 + 4	12mm	**1600**	**2500**	**1500**	2300	1200	2400	1200	2100
5 + 4	6mm	1200	2100	1100	2000	1000	1900	900	2000
5 + 4	8mm	**1350**	2300	1200	2300	1100	2150	1100	1800
5 + 4	10mm	**1500**	**2500**	**1400**	2300	1200	2350	1200	2000
5 + 4	12mm	**1650**	**2700**	**1500**	**2550**	**1300**	**2500**	**1300**	2150
5 + 5	6mm	1250	2400	1200	2100	1100	1950	1000	1950
5 + 5	8mm	1450	2500	1300	2500	1200	2250	1100	2200
5 + 5	10mm	1700	2550	1450	2600	1300	2500	1200	2400
5 + 5	12mm	**1900**	2650	1600	2750	1400	2700	1300	2550
6 + 5	6mm	1350	2500	1300	2200	1200	2000	1100	1900
6 + 5	8mm	1500	2750	1500	2250	1300	2300	1200	2200
6 + 5	10mm	1650	2950	1600	2600	1400	2550	1300	2400
6 + 5	12mm	1800	3100	1700	2850	1500	2750	1400	2600
6 + 6	6mm	1400	2900	1300	2650	1300	2000	1150	2100
6 + 6	8mm	1550	3100	1500	2700	1400	2350	1300	2250
6 + 6	10mm	1750	3100	1700	2750	1600	2450	1400	2500
6 + 6	12mm	1950	3250	1900	2850	1700	2700	1550	2600
6 + 6	14mm	2150	3350	2050	3050	1800	2900	1650	2800
6 + 6	16mm	2300	3550	2200	3200	1950	3050	1800	2900
6 + 8	10mm	2000	3200	1900	2900	1800	2550	1600	2550
6 + 8	12mm	2200	3300	2050	3100	2000	2600	1700	2800
6 + 8	14mm	2350	3500	2200	3250	2200	2750	1900	2800
6 + 8	16mm	2440	3850	2440	3300	2400	2850	2100	2850
8 + 8	10mm	2300	3200	2100	3100	1900	2850	1700	2900
8 + 8	12mm	2400	3600	2300	3200	2100	3000	1900	2900
8 + 8	14mm	2440	4000	2400	3500	2300	3100	2100	3000
8 + 8	16mm	2440	4000	2440	3950	2440	3300	2200	3200
6 + 10	12 mm	2440	4000	2200	3600	2000	3300	1900	3050
6 + 10	14 mm	2440	4000	2300	3900	2100	3600	2000	3250
6 + 10	16 mm	2440	4000	2400	4000	2200	3800	2100	3450
8 + 10	12mm	2440	4000	2300	3800	2150	3400	2000	3200
8 + 10	14mm	2440	4000	2440	4000	2300	3550	2150	3350
8 + 10	16mm	2440	4000	2440	4000	2440	3700	2300	3450
10 + 10	12mm	2440	4000	2440	4000	2350	3550	2100	3600
10 + 10	14mm	2440	4000	2440	4000	2440	3900	2300	3600
10 + 10	16mm	2440	4000	2440	4000	2440	4000	2440	3800

Table 1 Notes:

1. The maximum sizes are restricted by wind load deflections at 1.5 times the spacer width. (ie for 12mm space = 1.5 x 12 = 18mm) This ensures that under normal function the unit does not have poor performance and/or suffer Newtons Rings.
2. Unit sizes over 250kg in weight may require special handling, transportation and glazing requirements.
3. The size shaded is restricted by the normal maximum toughened glass size and the maximum IGU equipment size of 4000 x 2500mm.
4. Numbers in bold may exceed recommended toughening size for the minimum thickness
5. The size may also be restricted to comply with NZS 4223:Part 3:1999. This allows 1.5 x the allowable area for single glass.
6. The tables are for annealed glass combinations and are normally suitable for toughened glass and laminated glass. However, complex glass type, thickness and load combinations can be calculated using NZS 4223:2008 Part 1 and 4.
7. Unit combinations can be reversed (i.e. 4+5 = 5+4) for the same maximum size.