Cavity loads will include any effects that influence the pressure within the hermetically sealed insulating glass unit (IGU) cavity relative to external conditions, these include;

- Altitude
- Atmospheric (Barometric) Pressure
- Temperature

Determination of climatic loads for IGUs is not covered within Eurocode or British standards, and so guidance is typically sought from potential design conditions, or from European standards.

This document is not intended to provide comprehensive guidance, only a brief understanding of the elements that will influence climatic loads.

THE GAS LAWS

In order to understand the effects of climatic conditions on cavity loads, the gas laws, which consider pressure, volume and temperature relationships, need to be considered;

BOYLE'S, CHARLES' AND GAY-LUSSAC'S LAWS

Boyle's Law considers the relationship between pressure (P) and volume (V) at a constant temperature (T), which is inversely proportional, as such;

$$V_1 \cdot P_1 = V_2 \cdot P_2$$

Charles' Law considers the relationship between volume (V) and temperature (T) at a constant pressure (P), which is proportional, and as such;

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Gay-Lussac's law considers the pressure (P) and temperature (T) relationship at a constant volume (V), which as with Charles' law, is proportional, and as such;

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

THE COMBINED GAS LAW

Combined the three aforementioned laws yields the combined gas law, as follows;

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

AVOGADRO'S AND THE IDEAL GAS LAW

Avogadro's Law considers the relationship between the amount of gas (n, moles) and the volume (V), which is directly proportional, therefore;

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

This allows the ideal gas law to be derived, as below;

$$PV = nRT$$

Where R is the universal gas constant, and so is unchanged by conditions internal or external to the IGU. In addition, within a hermetically sealed IGU, the amount of gas will also remain constant.

Based on this, and with consideration to relative changes to the atmospheric conditions, the influence of pressure, temperature on a sealed IGU can be considered.

ALTITUDE

As altitude increases, atmospheric pressure reduces, as illustrated in the following chart. To illustrate this, the highest town in the UK is Flash in Staffordshire, at 463 m above sea level, which would be subjected to an atmospheric pressure 5 kPa below that at sea level.

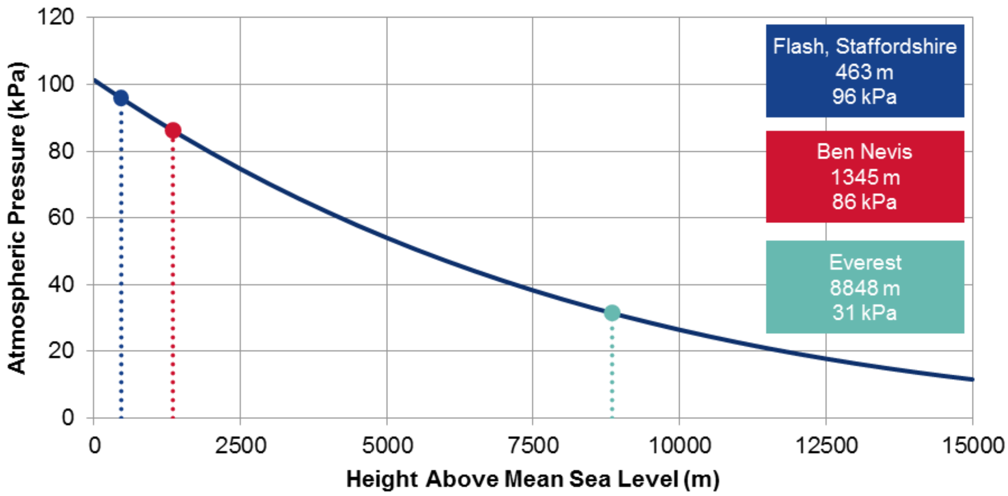

Figure 1 - Pressure Decrease with Altitude

It's important to note, that the building height will add to the overall height of the glazing, and would need to be considered for worst case calculations.

The pressure within the cavity is typically linked to the manufacturing altitude, and when the IGU is hermetically sealed, the amount of gas in the unit is fixed. As such, the altitude difference, commonly referred to as ΔH, will be relevant for the altitude at which the IGU is installed, relative to the altitude at which the unit is manufactured.

Where ΔH is positive, i.e. installed at a higher altitude than manufactured, the unit will bow outwards as the pressure imbalance leads to higher pressure within the unit relative to outside;

The opposite effect will occur where units are installed at a lower altitude than the manufacturing site.

In the absence of any specified altitudes to work to, TRLV and DIN 18008 [1, 2] both provide standard winter and summer conditions, which may be considered "worst-case" design conditions, as follows;

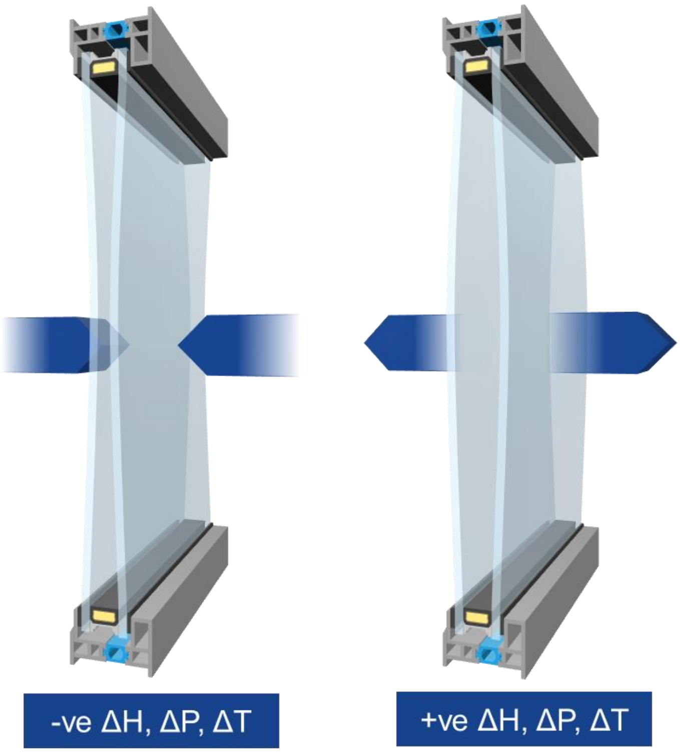

Figure 2 – Cavity Deflection Under Cavity Loading (Illustrative)

Table 1 - DIN 18008 Altitudes

Parameter	Winter Conditions	Summer Conditions
Altitude, ΔH	-300 m	+600 m

ATMOSPHERIC PRESSURE

Variations in atmospheric pressure relative to the atmospheric pressure at the time the unit was sealed, will also influence the loads, and is referred to as ΔP. It should be noted that the atmospheric pressure at the time of unit sealing is not likely to be recorded, and as such, this pressure will typically be an unknown.

As with changes in pressure due to altitude, a lower ambient pressure relative to the cavity pressure at manufacture, will lead to an outwards bow, whilst the opposite is true for a higher relative ambient pressure.

As with the ΔH value, TRLV and DIN 18008 both provide standard winter and summer conditions, which may be considered "worst-case" design conditions, as follows;

Table 2 - DIN 18008 Standard Pressure Conditions

Parameter	Winter Conditions	Summer Conditions
Cavity Pressure	0.099 N/mm^2	0.103 N/mm^2
Ambient Pressure	0.103 N/mm^2	0.101 N/mm^2
Pressure, ΔP	-0.004 N/mm^2	+0.002 N/mm^2

TEMPERATURE

Cavity temperature is the factor that will directly influence the pressure within an IGU cavity, as can be determined from consideration to the combined gas law. As the IGU will likely be, to some extent, flexible, the volume of the gas will increase in order to try and maintain the cavity pressure with the increase in temperature;

$$V_2 \cdot P_2 = \frac{P_1 \cdot V_1 \cdot T_2}{T_1}$$

In reality, the cavity volume wouldn't be expected to increase sufficiently to negate the full pressure increase, but a steady state will be reached when the pressure differential within the cavity is balanced by the bending stress generated in the glass.

As with the ΔH and ΔP values, TRLV and DIN 18008 both provide standard winter and summer conditions, which may be considered "worst-case" design conditions, as follows;

Table 3 - DIN 18008 Standard Temperature Conditions

Parameter	Winter Conditions	Summer Conditions
ΔT ($T_{Ambient} - T_{Manufacture}$)	-25 K	+20 K

Consideration should also be given to the effect of the cavity temperature resulting from solar control glasses with a high solar energy absorption, or spandrels. Guidance can be taken from TRLV and DIN 18008.

Table 4 - DIN 18008 Standard Temperature Conditions Changes

Condition	Effect	Temperature Change (K)
Summer	30% < Absorption ≤ 50%	+9
	Absorption > 50%	+18
	Internal Blinds (Ventilated)	+9
	Internal Blinds (Unventilated)	+18
	Applied Insulation to Rear	+35
Winter	Unheated Building	-12

COMBINED EFFECTS

As can be seen from the various "Summer" and "Winter" conditions, when considering the combination of ΔH, ΔP and ΔT, all three conditions act in the same direction, generation an overall "worst-case" outward acting and inward acting cavity pressure.

REQUIREMENTS FOR ASSESSMENT

In order to fully assess glazing with consideration to climatic loading, either the pre-defined loads within TRLV and DIN 18008 standards can be used, or more applicable climatic conditions can be determined, if manufacture and installation conditions are known.

When assessing glass under loading that includes climatic loads, both prEN 16612:2013 and prEN 13474:2009 [3, 4] provide methods to assess glass behaviour and load sharing. Within prEN 16612, a method for determining edge seal stress on an IGU is also provided.

REFERENCES

[1] Deutsches Institut für Normung, DIN 18008-1:2010-12 - Glas im Bauwesen - Bemessungs- und Konstruktionsregeln - Teil 1: Begriffe und allgemeine Grundlagen, Beuth, 2012.

[2] Deutsches Institut für Bautechnik, Technische Regeln für die Verwendung von linienförmig gelagerten Verglasungen (TRLV), DIBt, 2006.

[3] European Committee for Standardization, prEN 16612:2013 - Glass in Building - Determination of the load resistance of glass panes by calculation and testing, CEN, 2013.

[4] European Committee for Standardization, prEN 13474-3:2009 - Glass in building - Determination of the strength of glass panes - Part 3: General method of calculation and determination of strength of glass by testing, CEN, 2009.