Introduction

Windows and glazed cladding systems such as curtain walls are always required to meet specified performance criteria for air leakage. However, there are two different forms in which air leakage is reported, and this can cause confusion. This Technical Note explains the reasons behind, and the relationship between, different representations of air leakage.

Air leakage can be expressed as:

- A leakage flowrate per unit area of facade (or product)
- A leakage flowrate per unit length of joint

These different forms of expression can often be applied equally to the same component, but there are circumstances where one or the other is the more sensible:

a) Air leakage can occur through visible openings between parts of a component (even the smallest gaps may give an appreciable air leakage) or through invisible pores in the bulk of a material. In the first instance the length of the opening can often be measured, and used to derive a length-dependent air leakage rate, but in the second case the area of the pores is indeterminate and only an area-based rating is possible;

b) A component or facade designer needs to know the leakage per unit length in order to calculate the total air leakage through an assembly. The building services engineer or architect is concerned only with the overall leakage represented as leakage per unit area. If the unit area air leakage rate is specified by the architect/building services engineer then the component/facade designer can select and arrange suitable details to achieve that level of leakage.

The need to assess air leakage is based on two issues: energy use and thermal comfort. The energy use issue is obvious and usually dominates - air leakage through the facade implies an energy loss, which the services engineer must allow for when designing the heating and cooling systems. From a comfort standpoint the problem is draughts - openings which permit gross air movement can generate strong air currents causing discomfort, and possibly generate noise as well. It should be noted however that it is not always a requirement to eliminate air leakage; air leakage can provide a valuable background service in dispersing pollutants and odours, and in reducing humidity levels.

Leakage flowrate per unit area

For a facade as a whole (or a large-scale test sample which incorporates all of the features of the facade) the air leakage is expressed as a leakage per unit projected area, in m$^3$/hour/m$^2$. Figure 1 shows the allowable air leakage through a curtain wall, from Standard for curtain walling (CWCT, 1996).

Using an area-based leakage flowrate is the only option for large-scale facades and facade samples. The diverse components in a facade often mean that there are several different types of joint seal, and it can be difficult to identify the total length of joint - for example, a glazing unit may be mounted in a vent frame, which is fitted into a fixed carrier frame, which is fitted into a stick-system curtain wall frame, entailing three distinct joints between the glazing unit and the...
Representing air leakage through windows and glazed cladding systems

Figure 1 Allowable air leakage through facades

The only requirement is that there is just one type of joint, which can be measured - usually based on the visible perimeter of the joint. A typical performance requirement is given in BS 6375: Part 1 (1989), which states that for a window with only fixed lights the average air leakage rate should not exceed 1.0 m$^3$/hour per metre length of the visible perimeter of the glass or glazing material, when tested at the same range of pressures as for opening lights.

For products which have opening lights, such as a door or a casement window with a side-hung opening light, the situation is slightly different. Although the fixed joints contribute to the leakage through the window, the majority of the air leakage occurs through the opening joint; this is a necessary consequence of designing a jointing system that can be easily broken and

primary frame. In a large-scale test specimen there are also many types of joint which contribute to the overall volume of air leakage, and measuring the total length of ‘leaking’ joint may take longer than actually measuring the air leakage. It should also be noted that the contribution of each different type of joint can be difficult to assess.

Leakage flowrate per unit length of joint

Where a product has defined joints the air leakage can be expressed as the leakage per unit length of the opening joint, in m$^3$/hour/m. This is of particular advantage to manufacturers who from one test can estimate the maximum or minimum size of a product which will meet specified performance requirements. Figure 2 shows typical performance requirements from various standards.
BS 6375 ‘A’: class A rating for window from BS 6375: Part 1 (16 m$^3$/hour/m at 200 Pa)
BS 6375 ‘B’: class B rating for window from BS 6375: Part 1 (16 m$^3$/hour/m at 300 Pa)
BS 6375 ‘C’: class C rating for window from BS 6375: Part 1 (2 m$^3$/hour/m at 100 Pa)
DD 171 ‘W1’: class W1 rating for door from DD 171 (class W2 rating overlies BS 6375 ‘B’) (16 m$^3$/hour/m at 150 Pa)
CW ‘300’: 300 Pa rating from Standard for Curtain Walling (2 m$^3$/hour/m at 300 Pa)
CW ‘600’: 600 Pa rating from Standard for Curtain Walling (2 m$^3$/hour/m at 600 Pa)

Figure 2 Required air leakage through products with opening joints

rescaled - a good seal requires a high contact pressure, but a high contact pressure would significantly increase the force required to open and close a window or door. For such products the air leakage is expressed as a leakage flowrate per metre length of the opening joint, and the contribution of the fixed joints is assumed to be negligible. Of course, as better sealing technologies are developed and different forms of hardware are introduced (geared and electrically-operated hardware types do not suffer from the same limitations on operating forces) it is probable that opening joints will be made more air-tight, and eventually all air-leakage characteristics could be expressed as a leakage flowrate per unit projected area. However, at today’s level of technology, with (comparatively) poorly sealed opening joints it is still appropriate to use a different representation for air leakage at least for products with opening joints.

Advantages and disadvantages

Joint-length related air leakage characteristics have the singular advantage that they allow the user to estimate directly the performance of a product of a different size. For example, a manufacturer may have tendered a suitable design of window for a project as being a casement window, 900 mm wide by 1200 mm high, with a full-size opening light, and an air leakage of 4.0 m$^3$/hour/m of opening joint, at a specified reference pressure of 75 Pa (this complies with class B of BS 6375: Part 1). The
approximate joint length is 4200 mm (900+1200+900+1200 - the real joint length will be slightly less than this), and so the total window air leakage is 16.8 m$^3$/hour. However, the project architect then decides to set a limit of 10.0 m$^3$/hour air leakage per window. The permissible length of opening joint is therefore 10.0/4.0 or 2.5 m (2500 mm). This can be achieved if the window is re-styled as a top-hung opening light over a fixed pane, with the top hung light having a perimeter of less than 2500 mm (900 mm wide by 350 mm high). Figure 3 demonstrates these two styles of window.

**Origin of ‘Standard’ air leakage characteristics**

A point worthy of note is that the curves given in Figure 1 and Figure 2 are based on an assessment of what was sensibly achievable at the time that the standards were written; much higher performance is achieved by some manufacturers. Such curves are also generally of the form:

$$q = K(\Delta p)^n$$

- $q$ is the air flowrate in m$^3$/hour per metre or per m$^2$
- $\Delta p$ is the pressure difference in Pa

The exponent $n$ depends upon the nature of the flow; for laminar (streamline) flow $n$ is 1.0, and for fully-developed turbulent flow $n$ is 0.5. However, for a product with complex joints, of varying lengths and widths, the exponent $n$ is often somewhere between 0.5 and 1.0, due to there being a combination of laminar and turbulent flows. In the UK the exponent $n$ is taken as $2/3$ for windows and doors (BS 6375: Part 1), and Hutcheon and Handegord (1983) suggest a value of 0.65 as being suitable for many cases of window and wall leakage.

The variation of leakage flowrate with pressure differential for a typical glazed system is rarely a smooth curve, nor is it identical for positive and
negative pressure differentials. Figure 4 shows measured air leakage curves for different windows of the same size and style (900 mm wide by 1200 mm high, UK-style outward-opening top-hung light over fixed pane, opening joint perimeter 2760 mm) superimposed on the requirements of BS 6375. The air leakage is clearly not a smooth curve, and this can be explained by the relative movement of the various parts of the window when under pressure.

These tests were all performed using a positive pressure differential, with the higher pressure on the external face of the window. For a window which opens outwards this means that as the pressure increases the opening light is forced onto its weather-stripping, which usually increases the effectiveness of the seal. If the glazing gaskets are well-designed and properly installed then the overall air leakage can decrease as the pressure is increased. If the glazing gaskets are not properly installed or are poorly designed the air leakage through the fixed joints may then increase in a way that equals or outweighs the decrease in leakage through the opening joint.

It is usually the task of the specifier to identify the air leakage rate that is acceptable for the

![Figure 4](image-url)
products used in a particular project. However, the achievable leakage rate is often limited by the manufacturer’s choice of jointing method and the architects’ choice of pane or panel size.

**Effect of facade design on air leakage**

The window shown in Figure 3 is very simple compared to a curtain wall which combines fixed lights (vision and non-vision panels), opening lights, smoke vents and doors, and which may also abut other wall constructions and the roof. For such large scale constructions with a variety of joints the contribution of each to the overall air leakage is complex, and often hinders the comparison of facades which may contain the same components but in different proportions. The following examples illustrate this point:

**Case 1 - Influence of gaskets and their joins on air leakage**

Gaskets may be produced by injection moulding, linear extrusion or a combination of both. If moulded then the corners are an integral part of the gasket and can often be assumed to have the same air-leakage characteristics. However, if the gasket is formed from extruded (or a combination of extruded and moulded) pieces then joins may need to be formed in the gasket using

- heat-welding (thermoplastic rubbers)
- adhesive bonding
- butt- or mitre-joins buttered over with a wet-sealant
- dry butt- or mitre-joins

These different methods of joining gaskets have different degrees of success, because some rely upon the skill of the installer for a successful join. The air leakage rate of a made-up gasket, for example the gasket between a window frame and the glazing unit, can vary from the relatively air-tight frame gasket with moulded corners to the poorly installed ‘four lengths of rubber extrusion with visible gaps at the corners’ which offers little or no resistance to air leakage.

Beech and Saunders (1983) measured air leakage rates through linear pieces of a gasket and through jointed pieces of the same gasket. A 295 mm long linear piece of gasket was placed between two mortar surfaces (with the ends embedded in a sealant) and the air leakage measured for different pressures and degrees of compression. The same gasket was then formed into a square (inside measurement 145 mm per side, 580 mm total), with mitred corners sealed with a neoprene adhesive, and again tested at the same pressures and compression.

For a hollow section gasket, of a type commonly used to seal joints between cladding panels, the leakage flow rate past the linear section at 36% compression and 500 Pa pressure was measured at 22 ml/min per metre length. For the same pressure and compression the leakage rate in the mitre-jointed gasket was 140 ml/min per metre length. Each join therefore contributed a significant additional air leakage.

Based on these figures the actual leakage through the mitre-jointed gasket was 81.2 ml/min (140×580/1000), compared to an expected 12.8 ml/min (22×580/1000). Each join therefore contributed 17.1 ml/min ((81.2-12.8)/4); each of this type of join, in this particular gasket, therefore contributes an air leakage equivalent to an additional 777 mm (1000×17.1/22.0) of linear gasket.

Further information on gasket design and performance is given in *The performance of gaskets in window and cladding systems A 'state of the art' review* (CWCT, 1996).

**Case 2 - Influence of panel or pane size on air leakage**

Many facades comprise a uniform grid of rectangular infill elements, each with a gasket around its perimeter. However, as the grid spacing is reduced then the length of gasket per
Figure 5 The relationship between window style and air leakage rate

unit area increases, as does the number of corners per unit area.

Consider a curtain walling stick system which has been designed to be used in any type of facade, from a shop-front to a high-rise building. Let the air leakage, at a specified reference pressure of 75 Pa, be 0.2 $m^3$/hour per metre of frame.

If the curtain wall system is to be used as a shop front 3 m wide by 3 m high (Figure 5a) then the total length of frame per glazing unit will be 12 m (3+3+3+3), giving a total air leakage of 2.4 $m^3$/hour. The overall area of a unit is 9.0 $m^2$ (3.0×3.0) and so the area-based air leakage is 0.27 $m^3$/hour/$m^2$ (2.4/9.0), which complies with the 600 Pa rating of the Standard for curtain walling at the reference pressure.

If the curtain wall is to be used in a facade with a grid spacing of 1.5 m by 1.5m (Figure 5b) the total length of frame per unit is 6.0 m (1.5+1.5+1.5+1.5), giving a total air leakage of 1.2 $m^3$/hour. However, the overall area of a unit is now 2.25 $m^2$ (1.5×1.5) and so the area-based air leakage is 0.53 $m^3$/hour/$m^2$ (1.2/2.25), which only complies with the 300 Pa rating of the Standard for curtain walling at the reference pressure.

Now if the curtain wall is used in a facade with a grid spacing of 1.0 m by 1.0m (Figure 5c) the total length of frame per unit is 4.0 m (1.0+1.0+1.0+1.0), giving a total air leakage of 0.8 $m^3$/hour. However, the overall area of a unit is now 1.0 $m^2$ (1.0×1.0) and so the area-based air leakage is 0.8 $m^3$/hour/$m^2$ (0.8/1.0), which is too high to comply with either rating class in the Standard for curtain walling at the reference pressure.

Note: the conversion of air-leakage characteristics from one grid spacing to another is not always as straightforward; the corners of a gasket may experience a greater rate of air leakage if not properly sealed. For example, in the calculations above there are only 0.44 (4/9) corners per square metre for the 3m by 3m shop-front, 1.78 (4/2.25) corners per square metre for the 1.5m by 1.5m grid and 4.0 corners per square metre for the 1.0m by 1.0m grid. As the grid spacing is reduced so the corners also become relatively more important.

Large-scale testing for air leakage

The issues raised above have the greatest significance when testing facades or facade specimens to determine their air leakage characteristics. It is evident that project-specific testing on a sample which is representative of the particular application will give the most realistic assessment of the system performance, provided the same or better quality of fabrication and installation is then used on site. However, the
cost of such testing can be significant, particularly for small projects, and many facade suppliers would prefer to use existing test data to prove their system. Clearly the above example demonstrate that it is not straightforward to compare two different arrangements even of the same components. Care should be taken in assembling the test specimen that the numbers of joints and joins, and the total length of each type of joint is a sensible maximum for the test specimen; there would be some merit in assembling a specimen with two or more component spacings, and testing each area in turn.

It is also apparent that ‘standard’ values for air leakage often fail to recognise the range of constructions that are possible. For example, stick-system curtain walling may vary from basic systems with a large number of opening lights to practically airtight structural sealant glazed systems with no opening lights.

Summary

For the manufacturer it is useful to know the leakage through a product per unit length of joint. However, the number and complexity of joints in a facade require that overall air leakage be expressed per unit area, and such information is required by the architect and services engineer. There is clear scope for confusion, and yet it is difficult to resolve this problem (product manufactures cannot be expected to allow for the interface between their product and those from other manufacturers). It is important however that the designer understands the need for, and limitations of, both systems of representation.

References


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