Technical Note No 64

Gaskets

This Technical Note replaces CWCT TN 18. It describes the performance of gaskets and gives an approach to the design and selection of gaskets for glazing and other uses in the building envelopes.

This Technical Note should be read in conjunction with:

TN 16 Joints in the building envelope
TN 17 Weathertightness and drainage

Introduction

Gaskets are widely used to seal joints in building envelopes. Although they are apparently simple and inexpensive they are an important component in any system and they are a common cause of water and air leakage.

This Technical Note deals with the design of joints and gasket profiles and the selection of gaskets for use in different operating environments.

A gasket is a preformed component that provides a seal when compressed within a joint. The gasket may be compressed against a mating surface or another gasket.

Gaskets may be used to seal joints between fixed components (static gaskets) or to create opening joints around windows, doors and access openings (dynamic gaskets), Figure 1.

A range of polymeric materials are available for the manufacture of gaskets and gaskets are made in a wide range of profiles (cross-sections). Gasket design was seen as something of a 'black art' but the introduction of BS EN 12365 allows more of an engineered performance based approach to gasket design.

Gaskets should not be confused with sealing strips. These are preformed but rely to some extent on adhesion to one or both of the faces they mate against.

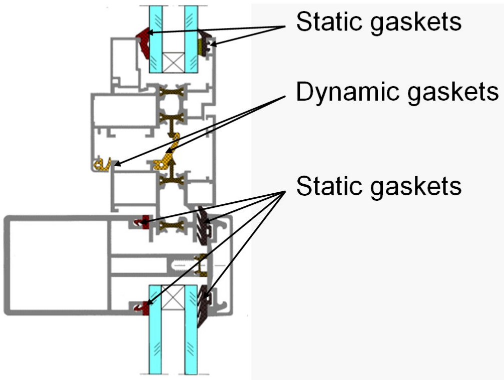

Figure 1 Static and dynamic gaskets

Nor should they be confused with sealant joints that are formed of a material that cures in the joint and relies on adhesion to both surfaces against which it mates. These are covered in CWCT TN 19 and TN 20.

Function of a gasket

Gaskets are primarily required to resist the passage of air or water or both through a joint. However there are other requirements that the gasket may have to meet. These include:

- Retention of components
- Transmission of forces such as wind load
- Low compression forces

- Allowing relative movement of components
- Accommodation of tolerances

Sealing
A joint should ideally comprise an inner and outer gasket to create a drained joint that provides a secondary defence against water ingress, CWCT TN 16, in which case the inner gasket is the primary air seal and the outer gasket is the primary water seal.

The term weatherstrip is sometimes used to describe a water seal while the term draughtstrip is sometimes used to describe an air seal.

In a drained joint the joint may be tolerant of small openings in an outer gasket, for instance at butted or mitred joints. In some cases the outer seal may be omitted and a protected opening relied on to limit the entry of water.

The performance of any air seal will be greatly affected by even small openings. There is virtually no air leakage between the gasket and a mating surface such as glazing, a glazing bead or pressure plate and most air leakage occurs at joints in the gasket. For this reason picture frame gaskets give the best air seal. These gaskets are formed with factory made corner joints to create a continuous rectangular gasket.

Transmission of loads
Wind loading on the glass is transmitted to the glazing frame through the glazing gasket. Windows are typically designed to resist windloads in the range 800 - 2000 Pa (0.8 – 2.0 kN/m^2). It should be noted that outward (negative) pressures lie in this range while inward (positive) pressures are lower in the range (0.6 – 1.6 kN/m^2). The mean force per linear metre on a glazing gasket can be calculated. The compressive force in a glazing gasket will be larger if the pane is larger. Doubling the length and height of a pane doubles the force on the glazing gasket.

Low compression forces
Compression forces in gaskets may have to be limited for several reasons;

- To limit the operating forces required to close a window
- To limit the compressive forces on the edge of a glazing unit
- For ease of installation

Operating forces for a window have to be limited to match the capacity of the human operator or actuator.

Operating forces are given in BS 6375. The force required to close a window and compress a gasket will depend on the stiffness of the gasket and the gasket deflection caused by closing the window. This is also affected by tolerances of the gasket and gap.

If the compressive forces in a gasket are too high they will cause high stresses in any glazing edge seal and may damage an insulated glazing unit.

Retention of components
A glazing gasket is required to retain the glass in position. That is not just to say that the glass should not fall from the opening. The glass should also be retained in a given plane and should not be perceived to move under contact loads.

A glazing gasket may also be required to apply load to a glazing bead to prevent it being dislodged.

Allowing relative movement of components
Movement of glazing, infill panels and frames may occur as a result of:

- Temperature change
- Applied loads
- Structural movement

Gaskets are required to allow one component to move in-plane relative to another so that only minimal force is transmitted from one to the other.

Accommodation of tolerances

The dimensions of the gasket profile can be controlled as described in BS 3734-1. There are also tolerances on the aluminium profile and the thickness of the glass or glazing unit, Table 1.

Component	Range of tolerances (mm)
Insulated glazing unit	± 1.0 or ± 1.5
Monolithic glass (up to 12 mm)	Up to ± 0.3
Patterned glass (up to 10 mm)	Up to ± 1.0
Aluminium window profile	± 0.7
PVC-U profile	± 0.3
Timber profile	± 0.5
Gasket (up to 10 mm)	Up to ± 0.8

Table 1 Tolerances affecting gap size

Gasket types

Gaskets belong to one of three categories depending on the construction of the gasket:

Brush gaskets

These comprise bristles mounted on a backing strip that may be compressed to provide an air or water seal. Their principal advantage is that the bristles slide easily across a mating surface. For this reason they are mainly used in sliding windows and doors. They are unlikely to perform as well as good gaskets of other types.

Cellular gaskets

These comprise cellular foam, normally sheathed to protect the foam and reduce friction between the gasket and mating surface. They are used principally as draughtstrips on opening lights and doors in dwellings.

Figure 2 Brush and sheathed gaskets

Non-cellular gaskets

These comprise a non-cellular polymer and may take one of several forms:

Push in gasket profiles have a foot that locates in a race in the frame. They are installed by simply pressing them against the race so that the foot engages in it.

Slide in gasket profiles also have a foot that locates in a race but they are slid into the race from one end.

Drive in gaskets, sometimes known as wedge gaskets are pushed into the gap between two components where they are retained by a nib that engages with a groove in the gasket.

Co-extruded blades may be formed on PVC-U glazing beads and polyamide pressure plates. These form a single component.

The stiffness of a gasket depends on both the stiffness of the material and the shape of the cross section. A solid gasket will be comparatively stiff and have little movement capacity. Making it hollow or adding fins at the interface with the mating surface can increase its flexibility and movement capacity.

A solid gasket profile may be a push-in, slide-in or drive in gasket.

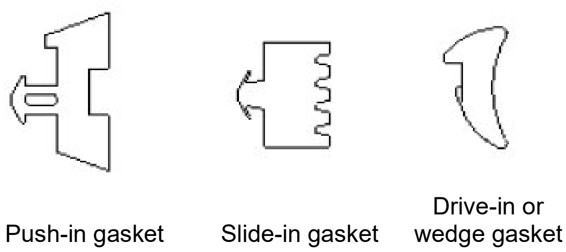

Figure 3 Solid profiles

A hollow gasket profile may be an O-gasket or P-gasket. These are commonly used as seals around opening-lights and doors as they give a good seal at low compressive force.

Figure 4 Hollow profiles

Fins may be added to most types of gaskets to make them more flexible in compression and easier to install. Adding fins to a push-in or slide-in gasket creates a fir-tree gasket. Adding fins to a wedge gasket creates an E-wedge gasket.

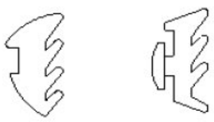

Figure 5 Gaskets with fins

A gasket comprising mainly a fin is called a flipper gasket. These are very flexible and have large movement capacity. They are used as mid-plane seals on doors and opening lights.

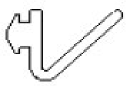

Figure 6 Flipper gasket

Typical uses of gaskets in a stick curtain wall system are shown in Figure 7.

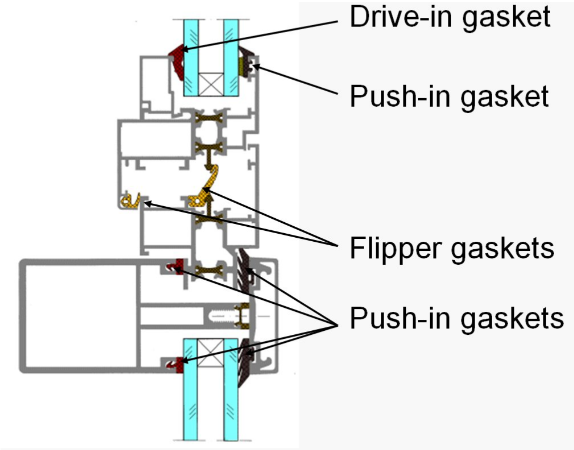

Figure 7 Typical uses of gaskets in stick curtain wall

Materials

Gaskets are made from polymeric materials (man made rubbers). They are seldom used as pure polymers but are blended with additives to:

- Modify their behaviour during manufacture
- Replace expensive polymer with economical filler
- Modify the in-service behaviour

Thus an EPDM, for example, can be blended to have a wide range of Shore hardness and/or deflection recovery.

The performance of a gasket is determined by both its geometry and the material properties of the polymer. For instance a solid profile of soft rubber may be stiffer than a hollow profile made from a harder rubber.

Material properties

DD 8455 gives test methods for some but not all of the properties described below.

Weathering

Gaskets may weather as a result of exposure to UV which causes cracking and fading of the material. A weathering regime is given in BS EN 12608 that may be used to assess this aspect of weathering performance.

Gaskets may also weather as a result of exposure to ozone which causes hardening and cracking. A test method is given in BS ISO 1431 and guidance on performance levels is given in DD 8455.

Hardness
The stiffness of most engineering materials is expressed as an elastic modulus. However, for highly deformable materials such as polymers it is difficult to interpret the results of a tensile test. Stiffness of the material is measured by an indentation test and expressed as Shore Hardness. For rubbers the Shore A scale is used and hardness lies on a scale from 0 – 100^0. Gasket materials normally have shore hardness in the range 55-75^0.

Compression set
Most gasket materials do not return to their original dimensions if compressed for an extended period and then released. Compression set is expressed as:

$$= \frac{100 \text{ x Final change in dimension}}{\text{Original change in dimension}} \%$$

Compression set is accompanied by stress relaxation. If a gasket is compressed into a gap of fixed width the stresses in it will reduce over time. Some manufacturers quote a stress relaxation factor expressed as:

$$= \frac{100 \text{ x Change in stress}}{\text{Initial stress}} \%$$

Ageing
Gasket materials become harder with time as a result of cross-linking of the polymer chains and leaching of plasticizers. This results in greater stiffness and reduced flexibility. Ageing is normally assessed by comparing the compression set of artificially aged specimens with that of specimens that have not been aged. Accelerated ageing tests are conducted by holding the material at elevated temperature for several days. This is best assessed by testing a gasket, as described below, rather than testing the material in some other configuration.

Tensile strength
Tensile strength of gasket materials is a good indicator of tear resistance. It is important when considering gaskets mounted on the edge of doors or opening lights.

A method for testing tear resistance is given in DD 8455.

Gasket properties

BS EN 12365 gives methods of test relating to gaskets, not simply materials. This is of far greater interest to the window, door or wall designer. The properties measured are:

- Stiffness
- Deflection recovery
- Aged deflection recovery

Stiffness
The stiffness of the gasket is measured taking account of both the material hardness and the gasket geometry. The result is reported as a working deflection range for the gasket (Table 2) and also the compressive force required to achieve the maximum deflection (Table 3).

Grade	Range (mm)
1	≤ 1
2	> 1 to ≤ 2
3	> 2 to ≤ 4
4	> 4 to ≤ 6
5	> 6 to ≤ 8
6	> 8 to ≤ 10
7	> 10 to ≤ 15
8	> 15 to ≤ 30
9	> 30

Table 2 Working deflection range to BS EN 12365-2

Grade	Linear compression force (N/m)
1	≤ 10
2	> 10 to ≤ 20
3	> 20 to ≤ 50
4	> 50 to ≤ 100
5	> 100 to ≤ 200
6	> 200 to ≤ 500
7	> 500 to ≤ 700
8	> 700 to ≤ 1000
9	> 1000

Table 3 Linear compression force to BS EN 12365-2

Deflection recovery

Deflection recovery of the gasket is measured to take account of its material properties and geometry. This is more informative than simply measuring compression set of the material and also it is measured at various temperatures.

Deflection recovery (Table 4) is reported for a defined working temperature range (Table 5).

Aged deflection recovery

Deflection recovery of a tubular specimen is measured after artificial ageing. The specimen is aged by holding it under compression at elevated temperature for 21 days.

The results are reported using the Grades shown in Tables 4 and 5.

Grade	Deflection recovery (%)
0	No requirement
1	> 30 to 40
2	> 40 to 50
3	> 50 to 60
4	> 60 to 70
5	> 70 to 80
6	> 80 to 90
7	> 90

Table 4 Deflection recovery to BS EN 12365-3

Grade	Range (^{0}C)
1	0 to +45
2	-10 to +55
3	-20 to +85
4	-25 to +100
5	-40 to +70
6	0 to +200

Table 5 Working temperature range to BS EN 12365-3

Material categories

Polymers used for the production of gaskets may be classed as thermoset or thermoplastic.

Thermoset polymer gaskets are formed by curing of the polymer. This creates cross-links that cannot be broken by heating the material. They normally comprise a single polymeric material blended with additives.

Thermoset materials were used when dry glazing systems were first developed and are still the dominant gasket material. However, thermoplastics have now been developed that can be suitable for glazing gaskets.

Thermoplastic elastomers (TPE) are formed by cooling the polymer in the desired shape. Reheating the material allows it to be reformed in a different shape. They normally comprise a blend of polymers.

Thermoplastic vulcanizates (TPV) are formed by vulcanising a thermoplastic polymer to give it properties closer to those of a thermoset polymer. They normally comprise a blend of polymers.

Thermoplastics have the advantage that they can be co-extruded onto glazing beads and pressure plates. They also have the advantage that waste material can be re-cycled within the manufacturing process.

Thermoplastic polymers have the disadvantage that they generally exhibit larger compression set than thermoset polymers. This may limit their use in some frame-gasket-glazing configurations.

Gasket materials

Non-cellular gaskets
Non-cellular gaskets may be formed from the following thermoset materials:

- EPDM
  Ethylene Propylene Diene Monomer
- Chloroprene
  Neoprene
- Hypalon
  Chlorosulphonated polyethylene
- Silicone
  Polymethlysiloxane
- Polyurethane
- Butyl rubber
  Isobutylene-isoprene copolymer
- Acrylic
  Alkyl acrylate copolymer

Or from the following thermoplastic materials:

- Thermoplastic elastomers
- Thermoplastic vulcanizates

Cellular gaskets
Cellular gaskets are formed from many of the materials used to form non-cellular gaskets. However, they are used in a closed cell sponge form and generally have to be protected with and outer sheath. This may be a fabric material or a co-extruded non-cellular skin of the same polymer.

Designing to seal

Firstly it is necessary to understand that the design of the gap is as important as the design of the gasket.

Secondly it is important to realise that the gasket profile is more important than the material properties when designing a gasket to provide a seal.

Glazing gaskets
The outer and inner glazing gaskets act together and are mutually dependent to provide the required seal.

The inner seal provides the air seal. Picture frame gaskets, comprising lengths of gasket and preformed corners assembled into a single component in the factory, provide a much better seal than separate lengths of gasket simply butted together at site.

The outer seal provides a water seal, although in a drained and ventilated system a small quantity of water may be allowed to pass the outer gasket.

Static glazing gaskets may be compressed by either:

- Compressing them into a gap of fixed dimension.
- Tightening down a pressure plate to give a known compression.

The approach to gasket design is different in each case as shown in Figure 7.

Gaskets in a pre-set gap
To compress gaskets in to a fixed gap one of the gaskets will be a wedge gasket. This is the most common arrangement for window and door glazing. In some curtain wall systems tightening the pressure plate to a stop rather than to a given torque creates a defined gap.

The width of the gap will determine the compressive forces in the gaskets at the time of installation. Note that these will depend on the actual gap allowing for tolerance of the frame, glass and gasket.

The first step is to determine the minimum possible gap and the compression induced in the gaskets as the wedge gasket is inserted. The two gaskets will be compressed by equal forces and the same force will be present across the edge of an IGU. This should not be so large that it damages the edge seal of the IGU.

Often different size wedge gaskets are available for use with different gap widths. This is a way of dealing both with tolerances and with glasses of different nominal thickness, for instance 6 mm monolithic glass and 6.4 mm laminated glass, in the same frame.

The second step is to establish that the gaskets will seal when they are inserted in to the maximum possible gap width and subjected to wind load. This is described below.

Gaskets with a pre-set initial force
In this case the gaskets are installed and then compressed by tightening down a pressure plate to a given torque. It is necessary to check that the compression induced in the each of the gaskets and across the edge of the glazing is not so large that it damages the edge of the IGU.

It is also necessary to establish that the gaskets will seal when subjected to wind load. This is described below.

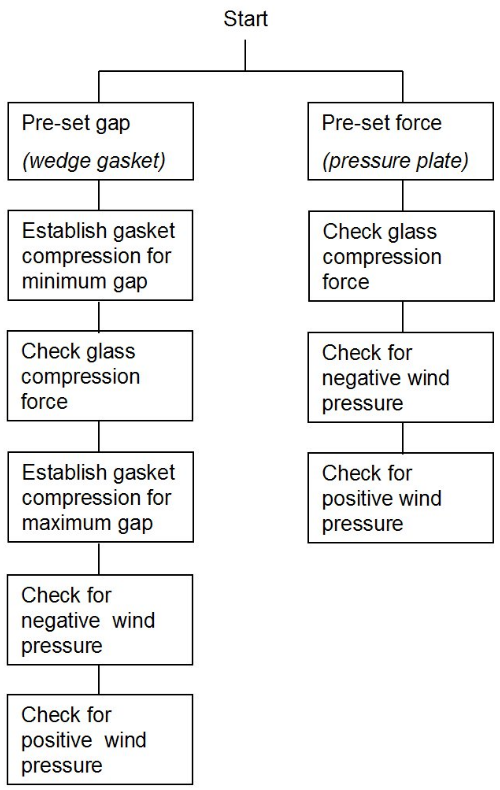

Figure 7 Design check for glazing gaskets.

Gaskets under negative wind load
Negative (outward) wind loads are equal to the design wind load. The window is required to limit air permeability at some lower pressure (peak test pressure) typically 300 or 600 Pa.

Under negative pressure the outer glazing gasket compresses. This may allow the inner gasket to separate from the glass or frame leading to unacceptable air leakage as exfiltration. Note that the outer seal will not provide an air seal if the glazing frame has drainage openings.

The inner gasket will expand to its original size less any loss due to compression set. The designer should check that the inner gasket continues to fill the gap under peak test pressure allowing for aged deflection recovery.

If the inner gasket is a wedge gasket and it is undersized then it may fall from the gap. The designer should check that under design wind load the inner gaskets are retained in position.

Gaskets under positive wind load
Positive (inward) loads are generally less than the design pressure but may be taken as equal to it for design purposes.

Under positive pressure the inner gasket becomes further compressed and its performance as an air seal will improve.

The outer gasket will expand to its original size less any loss due to compression set. It should continue to provide an adequate barrier to the passage of water and it should not become dislodged.

Opening joints

In an opening joint, around an opening light or door, the inner and outer gaskets are not opposed to each other and carry equal load. In opening joints the two gaskets are separately compressed each in its own gap of predefined width. The gap widths are defined by:

- The tolerance of the components, Table 1
- The adjustment of the closing hardware (locks, keeps etc.)
- The size of other gaskets at the joint

Note that the gaskets cannot be selected independently of each other. Selection of too large a gasket for one of the seals may increase the width of gap in which the other gasket is compressed. In an extreme case one gasket may be so over size that it prevents the other gasket from being compressed and forming a seal.

It is good practice to make the inner air seal with a softer gasket that works over a wider range of deflection. This will enable the inner gasket to seal for a greater range of gap widths and reduce any influence that the outer gasket has on the inner seal. In some windows the outer gasket is omitted and a protected drained cavity is relied on to limit water penetration. In some windows an intermediate gasket is used near the mid-plane of the frame, Figure 7. A gasket placed here will be a very flexible flipper gasket that works over a wide range of deflection.

Gap width is affected by the stiffness of the frames as well as the adjustment of the hardware. The gap varies in width and is a minimum at the hardware positions. For this reason multi-point locking is used on large windows and many domestic doors.

Under wind load the gaskets may be further compressed or the gaps they occupy may become wider. This depends on whether the windload is positive or negative and whether the door or window is inwards or outwards opening. For this reason air leakage may be very different when measuring exfiltration rather than infiltration.

Compression forces in the two gaskets are cumulative and together determine the force required to close the window or door. The allowable operating forces for windows are given in BS 6375.

Selection of materials

Ageing of materials

Materials may be selected to have a longer service life. In particular they may be selected to have resistance to hardening and long-term compression set. Material performance is generally as follows (in descending order):

- Silicone
- EPDM
- Neoprene

Colour

Gaskets are normally black and some gasket materials are only available in black. A wide range of colours is possible when using silicone or TPE gaskets.

Tear resistance

Gaskets that are exposed on the edges of doors and opening lights may be subject to tearing. Tear resistance of materials is generally as follows (in descending order):

- Neoprene
- EPDM
- TPE/TPV
- Silicone

Aggressive environments

If gaskets are to be used in specific aggressive environments such as industrial process plants it may be desirable to establish by test the effect of specific chemicals on the gasket material.

Manufacture

Gasket materials may be selected to facilitate manufacture or installation. In particular materials may be selected that can be co-extruded with other components of the frame, for instance TPEs that can be co-extruded with PVC-U.

Gasket materials may be selected so that joints can be vulcanised or bonded.

Temperature

Most gasket materials may be used at the operating temperature of UK building envelopes. Exceptions are:

- Very hot joints such as those around flues and pipework.

- Very cold joints such as those found in extremely cold climates and cold stores. Silicone retains its performance characteristics down to temperatures of -60^0C.

Cost

Gaskets make up a small part of the cost of a window or building envelope. However there is still pressure to minimise cost. Base material costs are broadly ranked as shown below in ascending order:

- EPDM
- Neoprene
- TPE/TPV
- Silicone

The cost difference has narrowed in recent years. Cost also depends on size and complexity of the profile and length of profile to be extruded.

Roll of design and testing

Gasket performance in windows and proprietary curtain walling is normally proven by testing air and watertightness. However, following the design guidance given above will be better than a process of pure trial and error.

Testing the performance of a window, door or wall will only show the performance of the newly installed gasket. An assessment of the long-term performance should be made on the basis of measured aged deflection recovery of the gaskets.

Substitution of one gasket for another or, in the case of opening joints, substitution of hardware should only be done if the performance of the gaskets in the new configuration has been assessed.

Gasket installation

Gaskets should be installed into clean gaps. They should not be twisted, kinked or stressed. Linear gaskets should be taken from the reel cut to approximate length and allowed to relax before installation. Any damaged lengths of gasket should be cut out and discarded. Picture frame gaskets should be unbundled and allowed to relax.

Gaskets should be of the correct width for the gap. Wedge gaskets may have to be selected to accommodate variations in glass type and thickness from opening to opening. It is good practice to indicate gasket size on the gasket. This may be by means of a colour coded co-extruded strip, Figure 8, or printed markings. Alternatively it may be by printed part numbers.

Gaskets should not be stretched during installation. A gasket that is placed in tension during installation will attempt to revert to its original length. This may lead to opening up of a simple butt joint or tearing of a bonded or vulcanised joint. It is good practice to include an anti-stretch feature in a linear gasket. This may be a cord enclosed within the gasket material or a rigid co-extruded strip, Figure 8. If no anti-stretch feature is incorporated in the gasket then it should be cut three per cent over length and put under linear compression as it is installed into the gap.

Uniform linear compression can best be achieved by following the installation sequence shown in figure 9. The corners (or ends) are inserted first followed by the mid-points. The quarter-points are then inserted and so on until the gasket is neatly compressed in the gap along its whole length.

Joints and corners

Gaskets may be formed into picture frame gaskets by bonding or vulcanising the corners in the factory. Alternatively corner joints may be formed at site by simple butt jointing, bonding or vulcanising.

Butt joints
Simply compressing two lengths of gasket, either end on or mitred into a corner, can form a successful joint. However, these joints are prone to poor workmanship and are most likely to be affected by opening up due to linear shrinkage of the gasket in the weeks and months after installation.

Bonding
Corners may be formed by mitring two lengths of gasket and bonding the mitred faces. However, the use of preformed corners that are bonded to the square cut lengths of gasket is generally more successful.

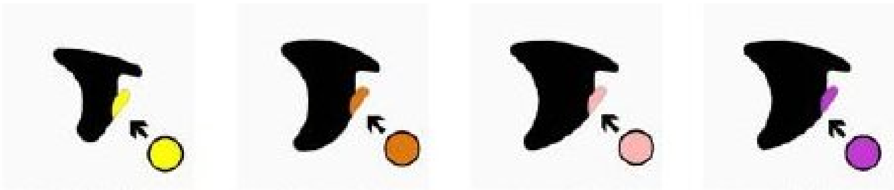

Figure 8 Colour coded anti-stretch strips on wedge gaskets

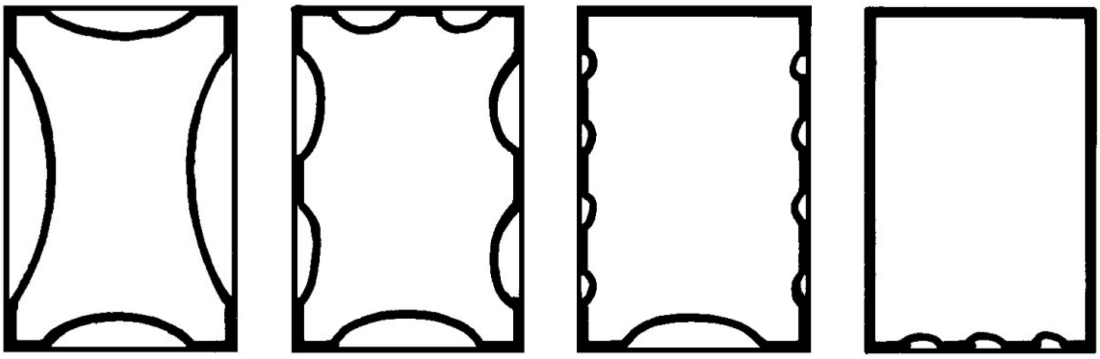

Figure 9 Sequence for installing a picture frame gasket

The adhesive used to bond a gasket has to be sufficiently flexible to maintain a bond when the gasket deflects in use. Only manufacturers recommended adhesive should be used. Bonding may be undertaken at site or in the factory in the case of picture frame gaskets. Bonding at site is prone to poor workmanship and adverse environmental conditions.

Vulcanising
As with bonding, lengths of gasket may be joined directly one to another, or to a preformed corner piece.

Not all materials can be vulcanised and vulcanising is a process that is best carried out in a factory to form picture frame gaskets.

References

BS EN 12365-1; Building hardware - Gasket and weatherstripping for doors, windows, shutters and curtain walling –

Part 1: Performance requirements and classification.

Part 2: Linear compression force test methods.

Part 3: Deflection recovery test method.

Part 4: Recovery after accelerated ageing test method.

BS EN 12608: Unplasticized polyvinylchloride (PVC-U) profiles for the fabrication of windows and doors - Classification, requirements and test methods

BS 3734-1: Rubber – Tolerances for products – Dimensional tolerances
BS 4255-1; Rubber used in preformed gaskets for weather exclusion from buildings – Specification for non-cellular gaskets.

BS 6375-2: Performance of Windows - Specification for operation and strength characteristics

BS DD 8455; Materials for gaskets and weatherstripping for windows, doors, Conservatories and curtain walling – Requirements and test methods.

BS ISO 1431-1; Rubber, vulcanized or thermoplastic - Resistance to ozone cracking - Part 1: Static and dynamic strain testing

CWCT TN 16: Joints in the building envelope, CWCT 1999.

CWCT TN17: Weathertightness and drainage, CWCT 1999.

CWCT TN 19: Selection and use of sealants, CWCT 1999.

CWCT TN20: Design of sealant joints, CWCT 1999.

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