Studies of the performance of weatherstrips for windows and doors

In the new and existing housing stock, considerable energy savings can be effected by improvements in sealing doors and windows. This also has the effect of improving the indoor climate.

Swedish Code of Practice, SBN 75, lays down specific requirements for the airtightness of doors and windows. The object of these requirements is to reduce heat losses by unintentional ventilation, i.e. air changes through points of leakage.

However, the ventilation of buildings must be at least so large that the hygienic requirements (regarding moisture, odours and possibly the incidence of radon) are safeguarded. The extent to which ventilation can be cut is open to debate, but an air change rate of 0.5 per hour is probably the least which is needed in a residential building.

Table 1. Highest acceptable air leakage (SBN 75).

Building component	Pressure difference Pa	Highest acceptable air leakage, m^3/m^2h, in buildings with the following number of storeys 1-2	3-8	8
Windows and doors opening into the open+	50	1.7	1.7	1.7
	300	5.6	5.6	5.6
	500	-	-	7.9

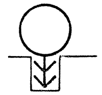
+ Relates to the airtightness of the gap between frame and casement or between frame and door leaf.

The scope of the investigation

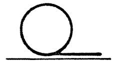
This report gives details of studies of the performance of weatherstrips for doors and inward-opening windows. It deals only with the seal between frame and casement, and leakage of air between the frame and the wall construction is thus not considered. All the investigations were perfo on new windows and doors. The results are therefore primarily applicable to newly produced doors and windows.

The effect of weatherstrips for doors and windows was assessed with regard to their sealing capacity and, in the case of doors, also the closing force required. The airtightness and closing force studies were performed as full-scale tests. The ageing properties of the strips were determined by the application of heat when the strips were compressed or extended.

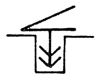
Weatherstrips: Types and materials



- Tubular strip (O-strip) with a toe for mounting in a groove. Is pressed into the groove.

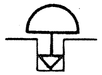


- Tubular strip (O-strip) for mounting on a flat surface. Self-adhesive or mounted by stapling, nailing or gluing.



- Angle strip (V-strip) for mounting in a groove. Is pressed into the groove.

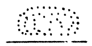
- Angle strip (V-strip) for mounting on a flat surface. Mounted by stapling, nailing or gluing.



- D-strip with a toe for mounting in a groove. Is pressed into the groove.

- Expanded strip for mounting on a flat surface. Self-adhesive.

- Foam strip for mounting on a flat surface. Self-adhesive.



- Fibre strip for mounting on a flat surface. Mounted by nailing or stapling.

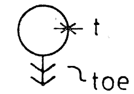
Weatherstrips in the modern sense of the term have a relatively short history in building technology. The strips which were first used, and which are still in use, were spun fibre strips of wool or cotton (with a diameter of about 8 mm.

Foam strips consist of foam plastics with open pores.

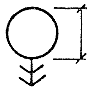
Expanded strips, i.e. porous rubber strips with closed pores, are comparatively new on the market.

Tubular strips are made in profile heights of about 5 mm and larger, and angle strips in heights of about 7 mm and larger. The materials most commonly used are synthetic rubber (EPDM, chloropene rubber and silicone rubber), and plasticised PVC.

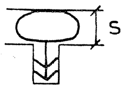
Symbols



t Material thickness of the strip. Does not include toe, if any.



h Height of unloaded weatherstrip. Does not include toe, if any.



s Width of gap between closed door leaf or casement and frame. The mounting groove, if provided, is not included. In the section dealing with deformation tests, s denotes the height to which the strips were compressed.

The performance range of the strip. This is the range, bounded by two values of s, over which a weatherstrip satisfies the requirements specified with regard to airtightness and closing force.

The performance range is limited upwards by the highest acceptable leakage of air, and downwards by the greatest acceptable closing force.

Ageing

Ageing investigations were performed on weatherstrips made of EPDM, chloropene rubber, silicone rubber and PVC.

Extension test: Four identical sets of strip samples of 100 mm length were weighed and mounted on sheets. One set was mounted in its original state, while the other three were mounted when extended by 5, 10 and 20% of the original length. The samples were then placed in a heating cabinet at a temperature of +60°C.

All chloropene strips which had been extended by 20% of the original length cracked and broke on the first day.

After some more days, one chloropene strip which had been extended by 10% broke. The other strip samples were still quite undamaged after 100 days, and no detrimental effect could be detected.

To sum up, the investigation showed that the materials EPDM, silicone rubber and PVC have a higher resistance to cracking under tension than chloropene rubber. This property is of great significance for weatherstrips of angular or tubular shape. When these strips are compressed between the mating surfaces of a door or window, the shape of the strip is deformed, and zones subjected to tension occur. In unfavourable cases longitudinal cracks may arise.

Deformation tests: The deformation properties of the strips were studied by compressing four identical sets of strip samples. Tubular strips were compressed to s=4.5 mm, and angle strips to s=6 mm. Two sets were kept in a heating cabinet at a temperature of +60°C, and the other two at room temperature at about +22°C.

Briefly, the test results showed that strips of silicone rubber had very small permanent deformations. EPDM and chloropene rubber strips had somewhat larger deformations. In all the tests, PVC strips attained the largest permanent deformations.

Our investigations therefore indicate that special rubber mixtures such as silicone rubber and EPDM are preferable to PVC for weatherstrips for doors and windows. The probable life expectancy of these synthetic rubbers is up to 10 years.

Airtightness

In determining the leakage of air, the "guarded pressure box method", a technique devised in the 60s at the Division of Building Technology, Royal Institute of Technology, Stockholm, was used.

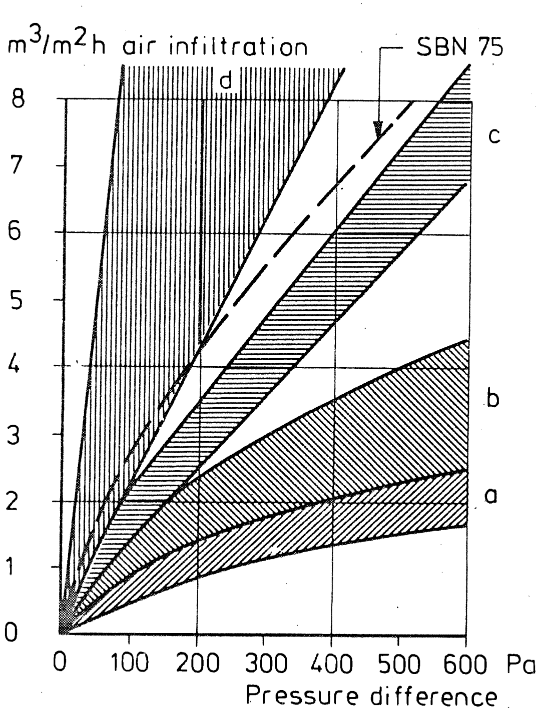
A measuring box was mounted with its open side towards the construction under investigation. The junction between the box and the construction was sealed very thoroughly. A guard box was placed outside the measuring box. Fans were used to generate a negative or positive pressure of the same magnitude in both boxes, with the result that there was no difference in pressure between the measuring box and guard box, and theoretically there was no movement of air between the boxes. All the air which was forced into the measuring box or was drawn out of this (via a gas meter) leaked through improperly sealed points in the investigated construction.

The accuracy of this method is satisfactory.

Windows

The leakage or air through weatherstrips in windows was determined for negative and positive pressures of up to 600 Pa. 22 weatherstrips were studied in the test window, 7 tubular strips, 6 angle strips, 3 expanded strips, 3 foam strips and 3 fibre strips.

The smalles air leaks occurred through strips of tubular or angular profile. (The value determined are shown in Fig. 1. For purposes of comparison, the curve showing the highest permissible air leakage according to SBN 75 is also shown in the figure).



a Tubular strips
b Angle strips
c Expanded strips
d Foam and fibre strips

Figure 1. Summary of results for weatherstrips for windows.

- On average, the larger tubular strips (h=8 mm) provided a better seal than the smaller ones (h=5-6 mm).
- The heights of the angle strips were between 6 and 9 mm. Owing to the scatter in the readings, a best height cannot be indicated.
- One foam strip of h=4 mm could also provide a satisfactory seal. In most cases, older types of strips such as foam and fibre strips did not meet the specified requirements.

Careful mounting, especially in the corners, is essential in order that a satsifactory seal should be obtained. Our opinion is that this is achieved most easily when tubular strips are used.

Doors

The leakage or air through weaterstrips in doors was determined at negative pressures of up to 300 Pa.

- In new external doors of wood, angle or tubular strips of synthetic rubber or PVC were exclusively used between the door leaf and frame. The width of gap is normally between 4 and 8 mm.
- 17 weatherstrips were studied in the test door, 11 tubular strips, 5 angle strips, and 1 D-strip. They were made of EPDM, chloropene rubber, silicone rubber and plasticised PVC.
- The strips could be assigned to 10 groups in which the values of air leakage and closing force were similar.
- The strips were mounted in a saw cut in the frame.

Performance ranges

Since most weatherstrips provide a better seal the more they are compressed, it is possible for even inferior strips to satisfy stringent airtightness requirements, provided they are sufficiently compressed. However, a large compression necessitates a high closing force, and for this reason a weatherstrip must be capable of providing a good seal even when only moderately compressed.

In order that the performance ranges of the strips may be ascertained, the leakage of air and the closing force were therfore determined for four gap widths between 4.5 and 8.5 mm.

The closing force was determined by suspending weights from a line which was attached to the door handle and run over a pulley. The door was opened 200 mm and released. The load was increased in steps of 5 N until the door lock engaged. For purposes of comparison, the closing force was also determined by two other methods.

In Fig. 2-5, the air leakage and closing force are plotted as a function of the gap width for 4 of the 10 groups of strips (4, 5, 8 and 9). The dashed curve indicates air leakage at 50 Pa, and the chain-line curve that at 300 Pa. The full curve indicates the force needed to close the door.

The horizontal full line in the diagrams is the upper boundary where air leakage is the highest value permitted in SBN 75, and where the closing force is 25 N (25 N is considered to be the highest acceptable closing force with regard to handicapped and old people). Since the curves are situated below this line, the strips satisfy the specified airtightness requirement and also have a low closing force.

The horizontal dashed line is the boundary for a closing force of 35 N. The rise in the performance range of a strip, when a higher closing force is permitted, can be determined with the aid of this boundary line.

Fig. 2 and 3 show the curves determined for the investigated 10 mm tubular strips which make up Groups 4 and 5. The wall thickness of the strip in Group 4 is less than that in Group 5. Both groups were very airtight over the greater part of the investigated gap width interval. The investigations showed, however, that the strip with a larger material

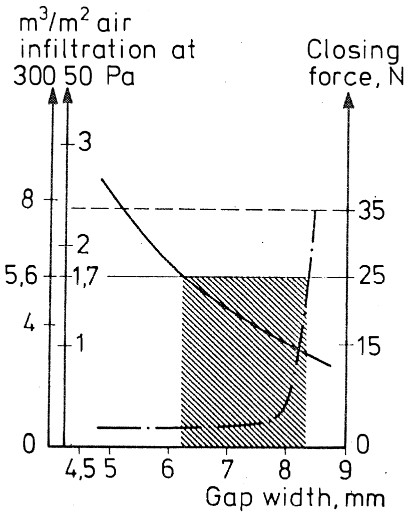


Figure 2. Tubular strips
(h=10 mm, t=0.8 mm).

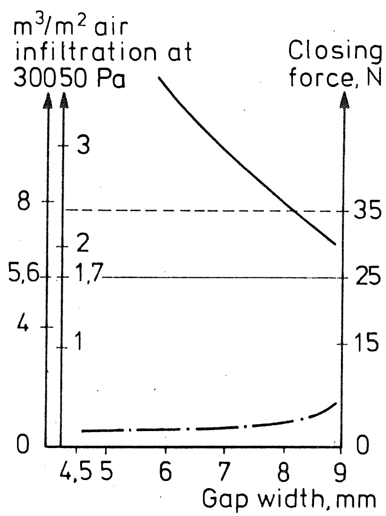


Figure 3. Tubular strips
(h=10 mm, t=0.95).

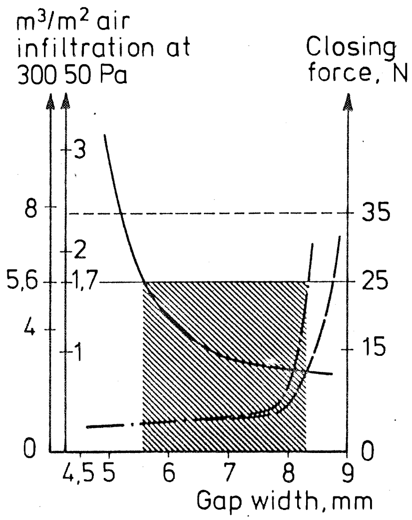


Figure 4. D-strips
(h=10 mm, t=0.6 mm).

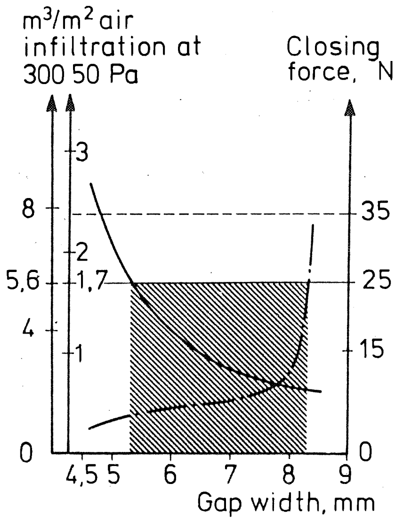


Figure 5. Angle strips
(h=11-12 mm).

——————— Closing force
— — — — — Air infiltration at 50 Pa
— · — · — " " " 300 Pa

thickness needed a considerably higher closing force than that with a smaller material thickness.

Fig. 4 shows curves for the D-strip (Group 8). Owing to its small wall thickness, the strip needed a fairly low closing force. This strip had a large performance range as it was also relatively airtight. Owing to the small wall thickness, the compliance of this strip with the airtightness requirement was somewhat inferior at 300 Pa to that at 50 Pa.

Curves for angle strips of 11-12 mm height (Group 9) are shown in Fig. 5. The angle strips had a large performance range. They had a relatively low closing force, but leakage of air was higher than in the case of tubular strips.

The performance ranges of all the ten groups are set out in Fig. 6.

At an upper limit of 25 N for the acceptable closing force, the best strips had a performance range of just over 3 mm. These were tubular strips of small wall thickness, and angle strips. With regard to tubular strips, the conclusion that could be drawn was that a smaller wall thickness gave rise to a lower closing force, but did not cause an increase in air leakage. However, airtightness at high pressures had a tendency to deteriorate for very small wall thicknesses. A wall thickness suitable from the airtightness and closing force standpoint appears to be about 0.7 mm.

If a higher closing force of 35 N can be accepted, all strips have a larger performance range, and a smaller gap width can be permitted. The greater the original height of the strip, the greater the increase in its performance range. Tubular strips of small wall thickness, and large angle strips, have the greatest increase in performance range.

No	Type	h	t
1	Tubular strip	7.5	0.60
2	Tubular strip	8	0.70
3	Tubular strip	8	0.80
4	Tubular strip	10	0.80
5	Tubular strip	10	0.95
6	Tubular strip	12	0.60
7	Tubular strip	12	0.95
8	D-strip	10	0.60
9	Angle strip	11-12	
10	Angle strip	12-14	

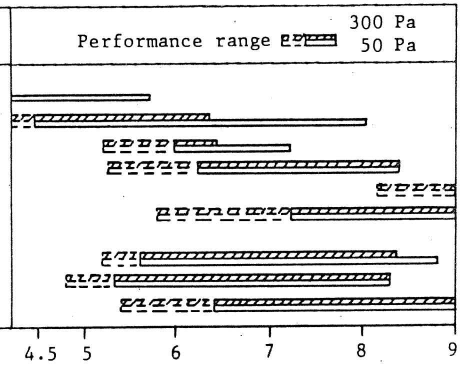


Figure 6. Performance ranges of weatherstrips for doors, with regard to air leakage and closing force. The full bar refers to a closing force of 25 N, and the dashed portion to 35 N.

In relation to their original height, the percentage compression of the strips at the upper and lower boundaries of the performance range was the same. If a closing force less than 25 N is to be obtained, tubular strips of small wall thickness should not be compressed to less than 60% of the height. However, they must be compressed to at least 80% of the height in order that the airtightness should be sufficient. Angle strips should be compressed to 50-70% of the height, while the corresponding values for D-strips are 55-80%.

Since the performance range of a weatherstrip is situated within certain percentage values of the compression, the range will be the wider, the greater the height of the strip. It is therefore best to give doors a large gap width and to select a weatherstrip of large height.

For the optimum value of the gap width, the best tubular strips had an air leakage only about one third of that of the best angle strips.

Practical cases

Investigations of the performance of weatherstrips were performed at the same time in old properties with natural ventilation, on the basis of the results of this investigation.

In order to determine the effect due to sealing the doors and windows, the old weaterstrips in windows were replaced by tubular strips. The front doors were provided with an angle strip.

The rate of air change in the building was measured by two different methods both before and after installation of the weatherstrips. The natural ventilation in 9 dwellings was determined by means of the *tracer gas method*. Installation of the new weatherstrips had the effect that there was a mean reduction in the air change rate from 0.9 to 0.5 per hour. In absolute terms, the greatest reduction occurred in dwellings which had a large air change rate prior to weatherproofing. After installation of the weatherstrips, air change rates in the different dwellings were relatively similar.

Four dwellings were subjected to a test pressure of 50 Pa. *Pressure testing* showed that the points of leakage were mainly situated at the windows. When the new weatherstrips had been installed, leakage of air during pressure testing dropped from 2.3 to 1.3 air changes per hour.

The buildings now have an airtightness of the same order of magnitude as that specified for new buildings.

Discussion

J.Cunningham, UNECE, Geneva, Switzerland:

Two questions with respect to the tests of ageing resistance of weather-strips:

Were the tests conducted in service conditions, or by laboratory techniques such as exposure panels?

You related effective life primarily to materials. For weatherstrips of the same material, have you observed any significant differences in ageing resistance of different profiles?

Höglund & Wånggren:

The test of ageing resistance were conducted in the laboratory.

To speed up the ageing the examined strips were stored in heat. In one test the strips were mounted on panels and compressed to about 50 % of their height. In another test the strips were also mounted on panels but stretched 5, 10 and 20 %. We did not observe any significant differences between the profiles.

It is important to state that even strips of the same material but made by different companies can differ in ageing resistance.

J.B.Siviour, Electricity Council Research Centre, Capenhurst, England:

I would like to ask three questions, first did your ageing tests consider whether the weatherstripping would be painted, second would they be removed during the painting process, and third what is the tolerance of the weatherstripping to warping.

Höglund & Wånggren:

The weatherstrips made of silicone-rubber can be painted over.

The normal procedure is however to take away the old weatherstrip, paint the window and then put up new strips. The strips are, compared with the painting-work, very cheap.

The tolerance to warping was determined for doors. The doorleaf was bent, like a bow, on the look side. For big (10-12 mm) tubular strips with thin walls and big (12-14 mm) angle strips the doorleaf could be bent 2-3 mm before the air leakage was too big. (According to the Swedish Code of Practice, SBN 75.)

John Greenland, NSW Institute of Technology, Sydney, Australia:

Sealing of doors and windows for the prevention of air infiltration and exfiltration can, if taken a little further, achieve acoustical insulation. Have you compared the standards required for each of these functions of door and window sealing in order to ensure that both benefits are achieved?

Höglund & Wånggren:

The paper presented at the CIB-Symposium does not cover this aspect. The link between acoustical insulation and airtightness is however fairly well known in Sweden.

An example: A door which meets the requirements of acoustical insulation is thereby also regarded as sufficiently airtight. (According to the Swedish Code of Practice, SBN 75.)

David T.Harrje, Princeton University, Princeton, USA:

One strip available in the USA that was not tested was the closed cell plastic; however, the best types, the tubular rubber and angular rubber are not available to my knowledge. Could you please comment on availability on world basis of the seals tested?

Höglund & Wånggren:

The question was passed on to one of the manufacturers of weatherstrips in Sweden.

The availability on world basis is good and in Sweden there is a small overcapacity. The machinery to make the strips is, however, common all over the world.

Michael Finbow, National Building Agency, London, England:

Which of the seals are effective in sealing existing windows and what is involved in fitting them to the window?

In which positions are the strips located in the frame (is the position different depending on which part of the frame is considered, i.e. hinged side or fastening side, head or sill)?

Höglund & Wånggren:

The question regarding weatherstripping of old windows is very difficult to answer in a general way. One of the reasons is that there are so many types of old windows and another one is that the old windows are aged and often warped. The best way to guide you here is to say that you should choose a tubular strip twice as thick as your width of gap.

The strips can be mounted by stapling, by a selfadhesive tape or in a groove specially made for this purpose. The best way to mount the strips on a Swedish standard inward opening window is shown in the figure.