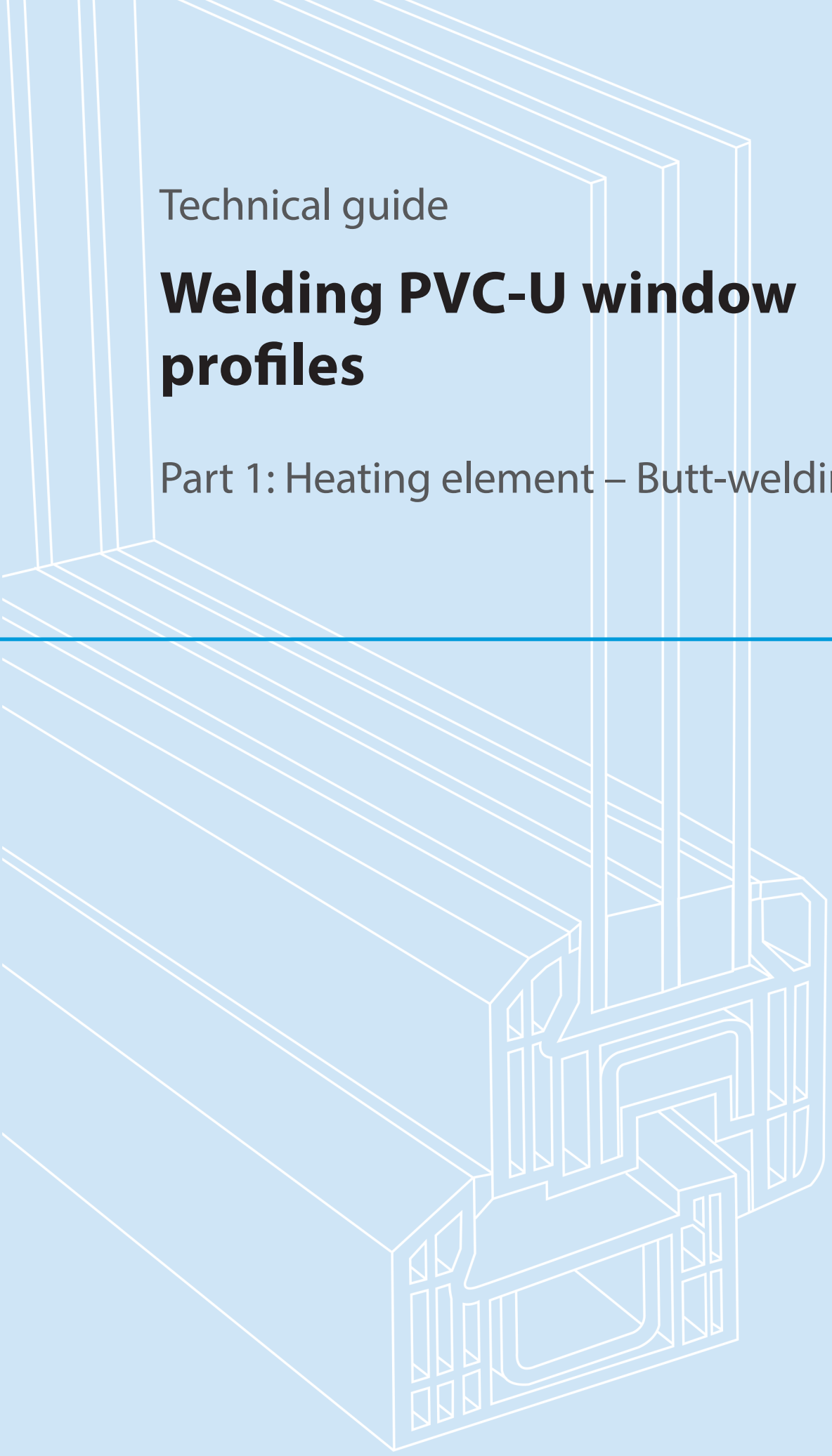
Technical guide

Welding PVC-U window profiles

Part 1: Heating element – Butt-welding



European PVC Window Profile and related Building Products Association

Welding PVC-U window profiles, Part 1: Heating element – Butt-welding

A guide for window manufacturers, profile system vendors, machine suppliers and component suppliers.
Brussels, December 2018

Content

1. Purpose of this guide

There has been an established market in the welding of PVC profiles for decades – and the process is important for the long-term durability of a window. Both PVC window profiles and processing techniques have become more complex over time, however. Our guide is therefore intended as a helpful reference, explaining terminology and thereby simplifying the coordination of the processes for all those involved. It is aimed at window manufacturers, profile system vendors, machine suppliers and component suppliers (e.g. film, reinforcement and sealing).

Our guide summarises the best available technology in the aforementioned industries. It takes into account all relevant standards and rules. Reference must also be made to the applicable specifications for profile systems and the operating instructions of the machine manufacturers.

The guide starts with the storage of the profiles and it includes tips from the correct cut and the welding process right through to the finished corner. There are useful facts about angle welding in particular.

In order to ensure quality, we indicate the major points at which routine factory production control (FPC) checks are needed in the welding process.

Our recommendations are specific to the profile categories which are defined in the RAL-GZ 716 Quality Assurance Guidelines (Technical Appendix Section I):

- PVC-U profiles
- PVC-U profiles, fibre-reinforced
- PVC-U profiles, PMMA co-extruded
- Profiles with surface finishing (film-laminated and coated)

and which meet the tolerance and corner strength specifications set out there.

2. Standards required of welded and finished profile joints

The correct construction of the corner weld is crucial for the long-term durability of a window. The welding process, as well as the preparatory work and finishing work, are therefore key to determining the quality of the workmanship.

The welded and finished frame joint is exposed to a wide variety of forces throughout the service life of the window, including the following:

- Working loads (glass weight, continuous function, wind load)
- Fastening and mounting fittings
- Additional loads due to absorption of forces, e.g. safety rails and burglar resistance
- Temperature-induced changes in the length of the profiles

3. Storage and in-plant transport

As a general rule, temperature control and cleanliness are important for the welding process, as is the avoidance of dirt and moisture, direct sunlight and heat sources . Particular care must be taken after the welding process to ensure the protection of the corner (to prevent breakage). Storage inside for 24 hours at a minimum temperature of 17 °C prior to sawing and welding is advisable (see also 5.1 Operator/window manufacturer). Further information can be found in the specifications of the profile system providers.

4. Cutting profiles correctly

The precision of the cut is fundamental in order to be able to meet the strength requirements of the corner joints. The cut also has a major bearing on the perfect appearance of the profile.

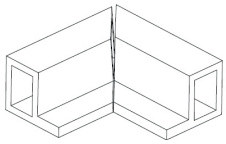


Fig. 0: Accuracy of sawing: Example to show how it should not be done (BPF)

The following points must therefore be taken into account when cutting the profiles to size:

- Dimensional and angular accuracy
- Flat, clean, grease-free, silicone-free and smooth cut surfaces, including in the sealing area
- Shatterproof ridges inside the water-bearing chambers

The quality of the cut depends on various factors, such as profile geometries and their tolerances as well as machine parameters, saw blades, fixtures and profile position. It is important to note that a double cut – both mitre cuts in one operation – can lead to larger variations in tolerance.

Cutting machines of the type used as standard in the industry are suitable for the cutting of profiles. It is important that the machines are serviced and cleaned regularly in order to be able to guarantee the necessary precision when cutting the profiles to size. Requirements in terms of tools to be used and machine settings can be obtained from the manufacturer of the welding machines. The use of supports may be necessary for sawing some profiles.

The quality of the cutting should be guaranteed by factory production control (FPC) checks. In order to check the size when cutting, we recommend using suitable tools and following a procedure such as that shown below (see Fig. 1a/b).

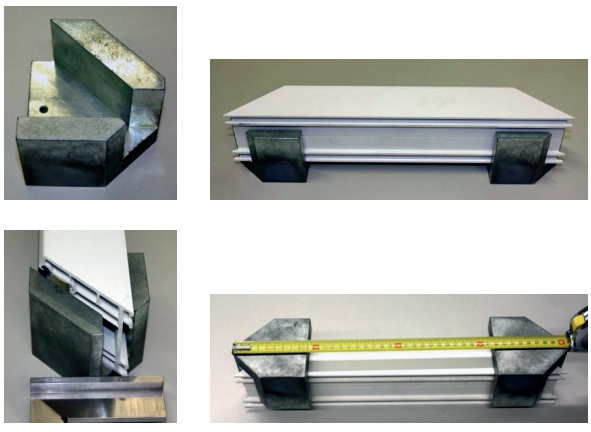


Fig. 1a: Manual measurement

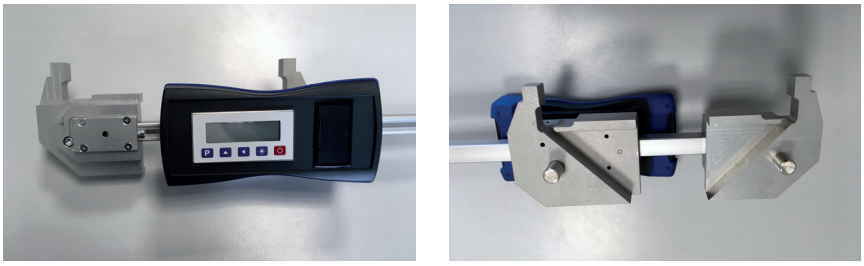


Fig. 1b: Electronic measuring devices

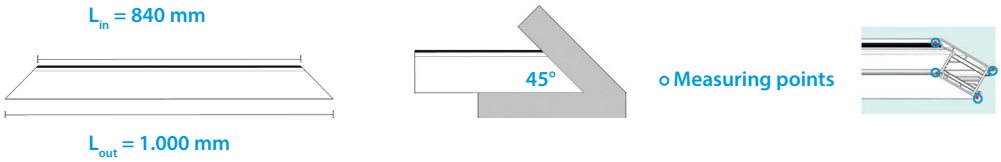


Fig. 1c: Three examples of different measurement positions: external and internal dimension, angle deviation and interface (f. l.)

4.1 Length allowance/Melting loss

When cutting the profiles to size, it is (absolutely) essential to add extra length to the finished dimension in order to allow for the join and fit. As a general rule, this should be twice the distance travelled on contact which will be needed for the subsequent welding process.

Fig. 2 illustrates the difference between the cut dimension and the finished dimension.

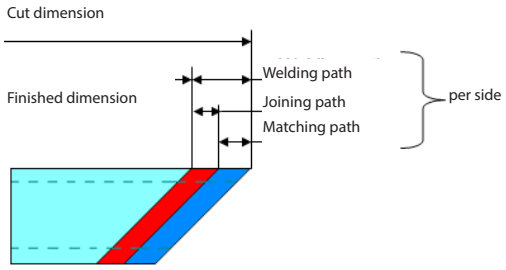


Fig. 2: Illustration of the length allowance/melting loss (= "welding path")

The melting loss depends on the process and on the machinery and affects both the appearance and strength of the corner join. The amount is usually between 2.5 and 3.5 mm. The lower the melting loss, the more important it is to comply with all the process parameters from cutting to size to finishing.

4.2 Weldable seals

When processing weldable seals, there are some points to bear in mind so as to prevent errors such as those shown in Fig. 3.

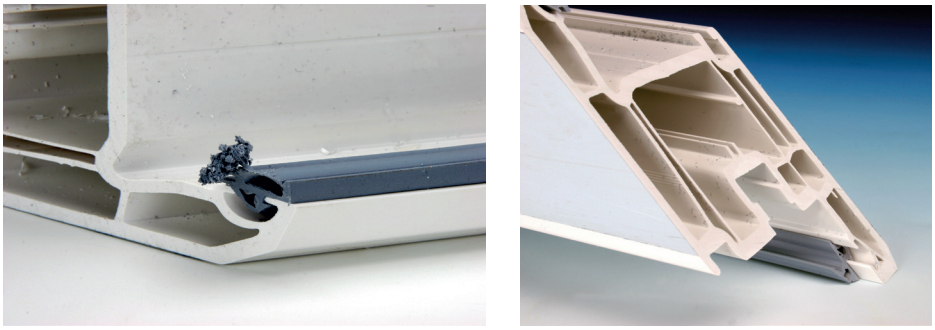


Fig. 3: Problems encountered with seals (f. l.): seal frayed or too short

You must ensure:

- An exact, clean cut of the seal (of the correct length)
- No detachment of the seal from the profile
- An intact seal (slight fraying which does not adversely affect the welding process and function is allowed)

In order to obtain a clean cut, use the appropriate saw blade for the profile and seal type and note the cutting direction. It may be necessary to use rests to support the profiles or devices to hold down the seals. This requirement can be discussed with the machine manufacturer or with the system supplier.

Depending on the design and nature of the seal, the flexibility of the corner may be improved by additional milling of the seal prior to joining. It is important that the milling process does not have a negative influence on the later function of the seal, so that the agreed performance characteristics (e.g. airtightness, resistance to heavy rain) of the window are guaranteed.

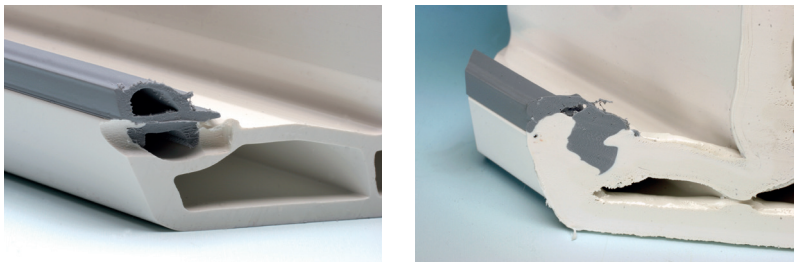


Fig. 4: Build-up without additional milling (l.) | Exemplary milling and shaping (r.)

5. Welding

The cut profiles are permanently joined together in the welding process. The welded unit must meet the three stated requirements:

- The corner strength specified by the system supplier
- The impermeability of the water-bearing chambers
- The finished dimensions of the window

The following diagram (Fig. 5) shows an example of the individual steps in the welding process. The actual temperatures, times and pressures depend on the system used and are specified by the machine manufacturer in consultation with the system supplier.

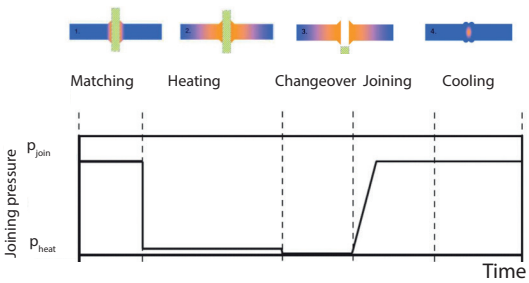


Fig. 5: The welding process consists of several steps

5.1 Influencing factors

There are three main factors which influence the welding process: machine, operator/window manufacturer and profile.

Machine
Profiles can be joined on all standard heating element butt-welding machines. The following machine parameters determine the quality of the welded joint:

- Temperature of the heating element on the active surface
- Clamping pressure
- Matching time and pressure
- Heating time
- Joining time and pressure
- Cooling time

Reference should be made to the instructions of the machine manufacturer regarding the specifications for the setting parameters, duly noting the specified values and tolerances of these parameters. Even if only one setting changes, this will affect all the others as well.

Operator/Window manufacturer
As the user, you too have a major influence on the end result in addition to the machine. The following points should therefore be noted:

- Avoid draughts around the machine in order to prevent uncontrolled cooling of the heating mirrors.
- Maintain a room temperature of ≥ 17 °C.
- Bring the profiles to the correct temperature before starting with the process if they have been stored outside or delivered to the site (24 h/17 °C as a rough guide) in order to prevent condensation from forming and to prevent the welding mirrors from cooling down too much.
- Weld the profiles as soon as possible after cutting (recommendation: within two working days) in order to keep the cut surface clean and dry.
- Service and clean your machines and systems regularly in order to prevent adverse effects on the sealing process.

It is generally not necessary to remove the protective film before the sealing process as long as the film will not adversely affect the end result. In addition, make sure there is sufficient clearance between the steel reinforcement and the sealing surface so that it does not get dirty and damaged when the steel is inserted. Note that steel may be contamined from sawing by suds or other lubricant fluid.

Please check with the machine manufacturer in advance if you are planning additional work on the unjoined part (e.g. attaching fittings), as this can lead to adjustments further on in the process when inserting the profiles and transporting the welded elements out.

Profile
Depending on the profile and system used, it is important to use suitable welding fixtures (mating contour of the profile being sealed). More information on this can be found in section 5.5. Due consideration should also be given to possible influences of coloured films or other coloured surfaces.

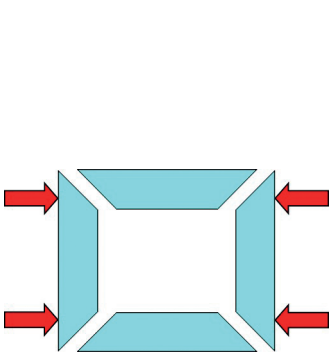
Note: If you use RAL quality-assured profiles, you can be sure that the material can be welded and that the dimensional accuracy of the profiles is guaranteed.

5.2 Types of welding

In angle welding, a basic distinction is drawn between diagonal and parallel contact pressure processes. Both processes are established on the market and meet requirements in terms of the corner strength, appearance and operability of the finished window.

Diagonal contact pressure
In this method, one bar is pressed diagonally against the other bar with „frictional" action. Looking at any given corner, only one bar is moved in the process. The other bar stays fixed in its position (Fig. 6).

The resulting displacement at the joint is unevenly distributed, as seen in the asymmetric bulges in Fig. 7 (right-hand part of the diagram).



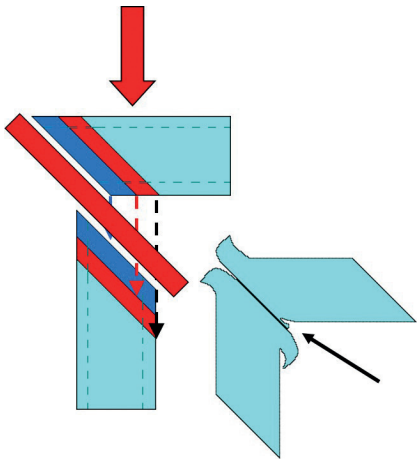
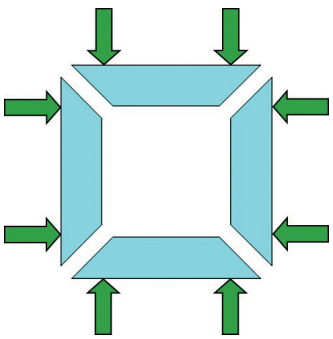


Fig. 6 (l.): The corner view shows that only one bar is moved diagonally

Fig. 7 (r.): The direction of movement is diagonal (i.e. at a 45° angle) to the joining surfaces (left-hand part of the diagram before joining; right-hand after joining)

Parallel contact pressure
In this method, both bars are pressed together at the corner at the same time (if possible) and the welding surfaces are pressed together in parallel (see Fig. 8). A symmetrical welding spruei is therefore formed.



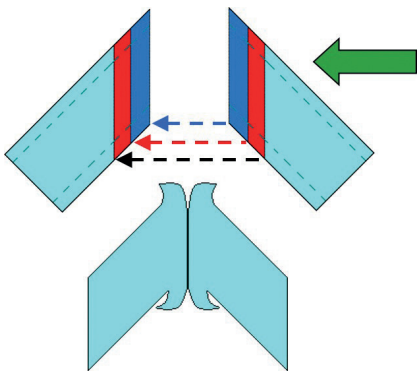


Fig. 8 (l.): Parallel pressure method

Fig. 9 (r.): The direction of movement is parallel (i.e. at a 90 ° angle) to the joining surfaces

5.3 Welding machine

An optimum joint is achieved with a machine which meets the following criteria:

- The clamping, matching and joining pressure can be adjusted with reproducible accuracy.
- The path control system ensures that the specified dimensions of the window are met.
- The exhaust air from the pneumatic system is not aimed directly at the welding mirrors (avoiding cooling).
- The clamping devices fix the profiles and transfer the force required for welding without damaging or deforming the profiles.
- The seatings of the profiles are firm and adjustable. An offset in the seam is to be avoided.
- The welding mirrors are readily accessible so that the film can be easily cleaned or replaced.
- The welding mirrors facilitate a uniform temperature distribution over the entire surface, including the film.
- The gap width and the temperature of the welding sprue limitation are adjustable.

5.4 Welding mirror

The welding mirror transmits the heat directly into the profile. The following points are important in order for the process to work properly:

- Keep the welding mirror clean.
- Use only undamaged and suitable PTFE film.
- Measure the temperature on the welding mirror in the welding area regularly with a contact sensor (see Fig. 10). Infrared thermometers must not be used because an air cushion forms between the PTFE film and the welding mirror which distorts the temperature reading.
- Clean the welding mirror with linen cloth or lining papers (not synthetic fibres).
- Avoid PTFE spray („Teflon spray“) because it can get into the seam and reduce the corner strength.
- When replacing bonded PTFE film, make sure that no adhesive residues are left on the heating element.

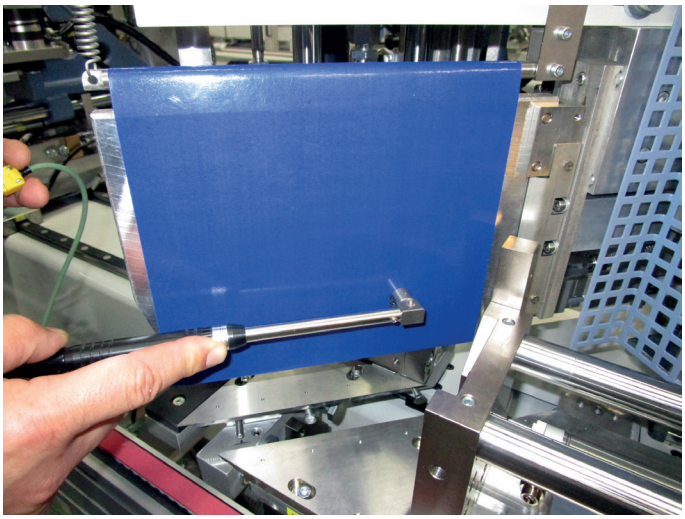


Fig. 10: Measuring the temperature on the welding mirror with a contact sensor

5.5 Welding fixtures

Aluminium blocks with the mating contour of the profile being sealed are commonly used as welding fixtures. Such fixtures (shown in red in Fig. 11) are used to fix and hold the profile in position. Their use depends on the profile and machine, and their suitability should be assessed in each individual case. On the one hand, these fixtures prevent the profile from deforming under the clamping pressure applied during the welding process. On the other hand, the fixture can restrict the sealing welding sprue.

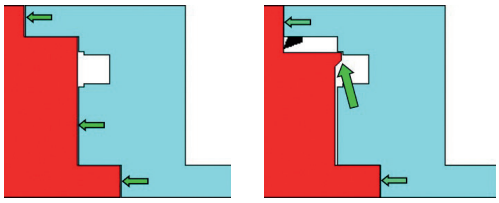


Fig. 11: System without seal (l.) and system with seal (r.); support in the fitting groove

As usual, the contact surfaces and dimensions of the fixtures need to be adjusted to the shape of the profile in any given case, their position in the machine and any special combinations, taking account of permissible tolerances.

Shapers and/or clamps can be used to improve the quality of the weld. In this case, it is important to make absolutely sure that the seals are not deformed by either the fixtures or the guide stops.

5.6 Welding sprue limitation

Welding sprue limiters are used so that the molten excess can flow off in a controlled manner during the welding process. They are usually between 0.2 mm and 2 mm.
As a general rule, the lower the limitation, the more important it is that all process parameters are met. This includes all the processes, from cutting to size to finishing, because they all affect the corner strength.

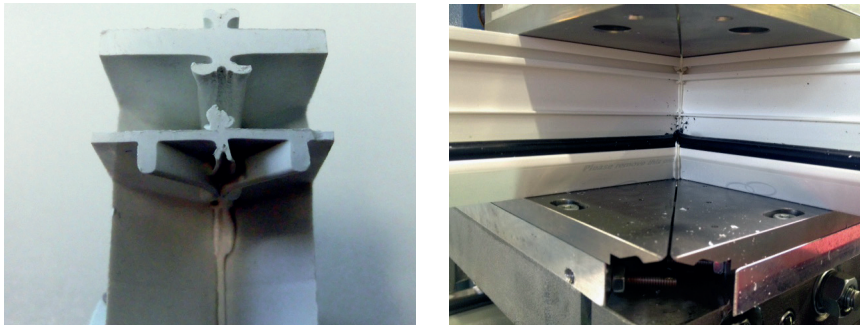


Fig. 12: Profile section showing welding sprue limitation (l.) | Welding sprue limitation in the welding machine (r.)

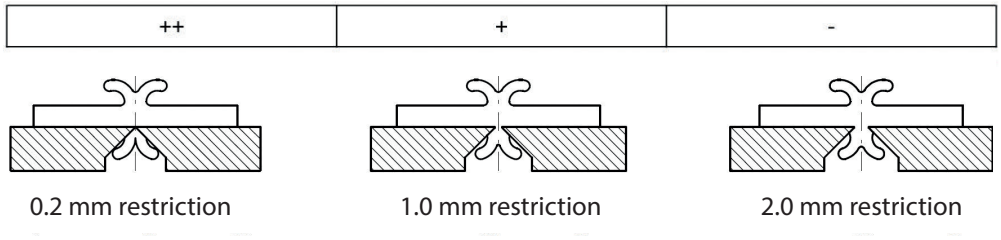


Fig. 12a: The Influence of the adjustment of the restrictor knives

+ = with effect | +++ = with large effect | - = with no effect

5.7 Process parameters

The recommended welding temperatures are usually between 235 °C and 255 °C but temperatures of up to 285 °C are also possible for special procedures, e.g. high-temperature welding.

In order to achieve optimum results and to attain the specified corner strength, it is necessary to take account of the following factors when adjusting the pressure (force) and time settings:

- Settings, recommended by your machine supplier
- Specifications, recommended by the window profile supplier
- Selected temperatures
- Welding sprue limitation
- Length of welding allowance or melting loss

5.8 Cooling

After welding, the profile must be left to cool down, which will take between one and 15 minutes depending on the profile. The cooling process must not be accelerated in any way, e.g. by using compressed air. You must also ensure that profiles are not placed on cold floors, in order to prevent them from cooling down too quickly (risk of stress).

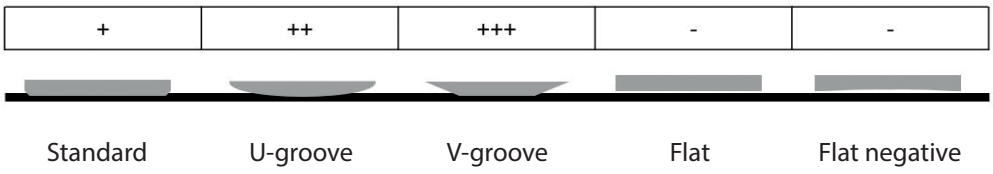
It is also important in this context not to interrupt the chain between the welding and finishing processes – duly allowing for the necessary cooling time.

6. Finishing

Once the welded profile has cooled, it is then finished. This involves removing welding sprues from the visible and operational part of the profile.

You must make absolutely sure that no holes have been caused by milling too deep; functionally relevant (e.g. water-bearing) internal chambers must remain closed. It is also important to check that the seal is still intact and fit for purpose.

The decision as to the shape of the groove (width/depth/inclination of the flank) is made in each individual case during the finishing process based on visual considerations. The options include U-shaped or V-shaped grooves or a smooth (flush) finish. It is important that the strength of the finished corner is as specified after finishing, that the seal sits on the surface of the finished profile corner without leaving any gaps and that no water penetrates through the groove.



\+ = with effect
\+++ = with large effect
\- = with no effect

Fig. 12b: Impact of the shape of the groove on the corner strength

6.1 Requirements on finishing

- Do not remove the welding sprues until the profile has cooled down sufficiently (especially in case of profiles with decorative film).
- Avoid indentations, especially on inside corners.
- Work very carefully, especially on operational parts (installation of fitting in Euro-groove and evenness of sealing contact surfaces, etc.), see „finishing finish“ and „mitre groove“ in the illustration below).

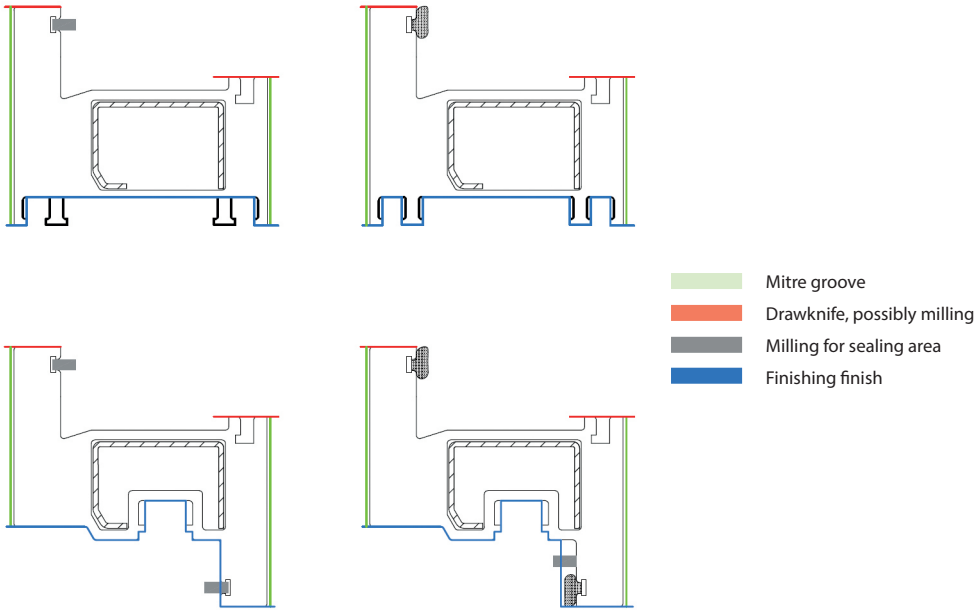


Fig. 13: Finishing in the functional areas

6.2 Special features of profiles with decorative surfaces

When working with decorative surfaces, particular care should be taken to ensure that the sensitive areas of the coloured decorative surfaces are not damaged during the finishing process.

A suitable touch-up applicator should be used to match the colour of the finished corners to the decorative finish. In case of coloured base areas, it can be used for colour retention and will cover any stress whitening which may occur.

When finishing laminated profiles, it is essential to adjust the profile height (overall depth) due to the thickness of the adhesive and the film.

Fig. 14: White fracture

7. Practical tips for quality control

This section contains tips based on professional quality control practices of the entire production process with special attention to the welding process. We advise window manufacturing companies to include these in the factory's own process control – if not already available.

To be noted for the German market: In addition to in-house quality specifications, the specifications from the processing guidelines of your system suppliers, other component suppliers (e.g. hardware and glass), the quality associations for multiple-pane insulating glass, locks & hardware as well as windows, facades and doors and the machine suppliers must also be taken into account. These are listed in the following table.

Material intake no. **Result** (mark with x)

No.	Property requiring testing	Frame material	Recommendation according to	Test method	OK	Not OK
1 (R)	Melting time	PVC-U	System description	Time measurement	☐	☐
2 (R)	Melting pressure	PVC-U	System description	Pressure gauge	☐	☐
3 (R)	Joining time	PVC-U	System description	Time measurement	☐	☐
4 (R)	Joining pressure	PVC-U	System description	Pressure gauge	☐	☐
5 (R)	Welding sprue	PVC-U	Even and limited, without any discolouration	Visual inspection	☐	☐
6 (R)	Frame outside dimensions	All	Order documents ± 1 mm	Measurement	☐	☐
7 (R)	Finishing work	PVC-U	Uniform groove[1]	Visual inspection	☐	☐
			No feathering	Visual inspection	☐	☐
			No notches	Visual inspection	☐	☐
8 (R)	Adhesive application	Metal	System description, on the joining surfaces	Visual inspection	☐	☐
9 (R)	Misalignment of profiles	All	System description	Measurement	☐	☐
10 (R)	Tightness of butt joint	Metal	Tight	Visual inspection	☐	☐

Fig. 15: Recommendation of the Gütegemeinschaft Fenster, Fassaden und Haustüren e.V. and the Gütegemeinschaft Kunststoff-Fensterprofilsysteme e.V. (RAL quality associations for windows, facades and doors and for PVC window profile systems)

[1] See section 6 „Finishing" and further requirements if necessary

Quality control must extend to all areas of manufacturing. We recommend setting up the following five "checkpoints" in the manufacturing process:

1. Storage and transport
- Check that profiles are in perfect condition.
- Check that profiles are clean and dry.

2. Cutting to size
- Check cut dimensions, length and angularity.
- Check cut surface and seals.
- Check that there is sufficient distance between reinforcement and cut surface.

3. Welding
- Check that PTFE film is clean and intact.
- Check that temperature and measurement settings are adjusted to the profile and that the fixtures are correct and undamaged.
- Check temperature on welding mirror.
- Check evenness of seating on the welding machine.
- Check parameter settings on the welding machine.
- Check dimensions of finished frame.
- Check uniformity of welding sprue formation (symmetrical and even over the mitre).
- Check colour of the welding sprue.
- Check flexibility and condition of the seal.
- Check that the decorative film is not damaged.
- Check that there are no residues of protective film in the seam.
- Check for leaks from the water-bearing chambers.
- Check cooling time.

4. Finishing
- Check that the finishing machines are on the correct settings (visible surfaces, operational areas, seals, size allowance with laminated profiles etc.).
- Check the inside corners (avoidance of notches, proper finishing in glazing strip groove).

5. Finished parts inspection
- Check corner strength (sample inspection), see 7.1.

Inspection intervals

As a window manufacturer, it is up to you to decide on the frequency of inspections. If you are subject to a quality control system, you will be required to comply with the relevant specifications.

We generally recommend carrying out tests when starting the systems and when changing the parameters.

7.1 Checks on corner strength

The required corner strength will depend on the shape of the profile. The corner strength reference value ($F_{req.}$) is specified by the system supplier together with the cut dimensions of the test samples (L_i and L_a).

Quality control checks on the entire welding process at the window manufacturer involve inspecting a corner which has been welded and finished, including welding sprue limitation where applicable.

Standard, commercially available tension/compression testers are suitable for the corner strength tests. The corner strength is identified with reference to EN 514. The following diagram applies for the "Compression bending test":

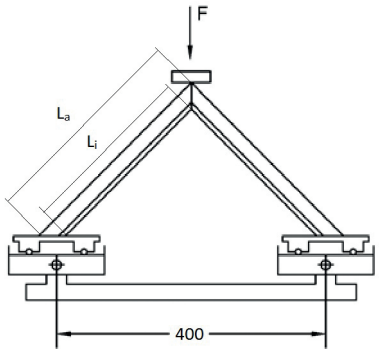


Fig. 16: Compression bending test used to test corner strength

In addition to the aforementioned test conforming to EN 514, a simple in-process visual check can be carried out on the quality of weld, as illustrated in the table below:

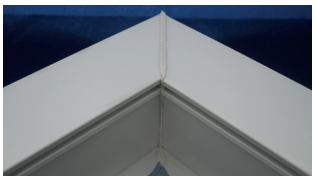
Image	Description	Causes of defect
	Clean, evenly formed welding sprue, no misalignment, visually neat welding pattern	No defect weld. OK
	Uneven, slightly displaced welding sprue	Machine angle adjustment, machine parameters (pressures, forces etc.), fixtures, contact/joint surface, cut, profile tolerances
	Yellow discolouration within the welding sprue	Times too long, temperature on heating element too high
	Foreign particles within the welding sprue	Dirt in the cut surface

Fig. 17: Simple visual inspection chart

7.2 How to avoid mistakes during welding processes

Errors during the welding process as well as in the preparatory and finishing work can adversely affect the quality of the corner strength. The following troubleshooting guide summarises the main ways of avoiding errors.

Problem	Remedy
The temperature on the display does not match the temperature on the welding mirror. The welding mirror cools down on one side (e.g. due to a draught).	Check the temperature with a temperature gauge. Contactless measuring devices are not suitable for temperature measurement. Check the location of the welding machine. (See section 5.4 "Welding mirror")
The time selected for cooling was too short (especially with laminated profiles).	Check parameters/times. (See section 5 "Welding")
The surfaces which are to be welded are dirty or damp.	Clean the cut surfaces before sealing; profiles which have been cut to size must be sealed quickly. (See section 4 "Cutting profiles correctly")
The PTFE film is dirty or damaged.	Clean the film or replace damaged film. (See section 5.4 "Welding mirror")
The surfaces being welded are not parallel to the profile flange due to incorrect clamping or poor cutting.	Make sure that the profiles are parallel to the flange (45°). (See sections 4 "Cutting profiles correctly", 5.3 "Welding machine" (clamping), 5.5 "Welding fixtures")
The profile is deformed during the clamping process.	Adjust the clamping pressure. (See sections 5.1 "Influencing factors", 5.3 "Welding machine" and 5.5 "Welding fixtures")
The weld at the water-bearing levels is leaking.	Check the entire production batch; repeat the welding process and ensure that the correct parameters are set. (See section 4 "Cutting profiles correctly")
Machining marks during grooving process (blunt grooving knife)	Avoid excessively long cooling times. (See section 5.8 "Cooling") Use a new/sharp grooving knife. (See section 6 "Finishing")

8. Further information/Other applicable documents

More information can be found in the following documents in addition to the instructions, information and specifications in this guide:

- System descriptions and processing guidelines provided by the PVC window profile system suppliers
- RAL-GZ 716 quality and test requirements (RAL quality associations for PVC window profile systems)
- RAL-GZ 520 quality and test requirements (RAL quality associations for multiple-pane insulating glass)
- RAL-GZ 607 quality and test requirements (RAL quality associations for locks and hardware)
- RAL-GZ 695 quality and test requirements (RAL quality associations for windows, facades and doors)
- Protocol template „Workplace-related self-monitoring: 3.3.6 Sash and frame assembly“ of the Gütegemeinschaft Fenster, Fassaden und Haustüren (Quality Association for windows, facades and doors)
- DIN EN 514
- Operating instructions of the machine suppliers

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Your notes

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