GUIDELINES FOR
WELDING OF PVC-U PROFILES FOR WINDOWS AND DOORS
(REFERENCE 332/2 2003)
1 Foreword

These guidelines have been prepared by the Technical Committee of the British Plastics Federation. Welding is a convenient, long established method for joining PVC-U profiles. It is an integral part of the process used in the manufacture of PVC-U windows and doors.

The purpose of these guidelines is to state the requirements and recommendations to be met in order to obtain satisfactory welds. It is intended to be used as a practical guide by fabricators.

When new or refurbished welding machines are being commissioned, the machinery suppliers may have their own set-up procedures. The procedures set out in these guidelines are when no other suitable guidelines are available.

This document has been prepared using information from a variety of sources which represent the best of current manufacturing experience and academic expertise. Special acknowledgement is given to the work originating from Arbeitgemeinschaft Industrieller Forschungvereinigung e.V., Cologne, and the German Association for Welding Technology (draft guideline DVS 2207, part 25, October 1989).

Compliance with these guidelines does not of itself confer immunity from legal obligations, and so this document cannot be used in legal disputes.

Health and safety requirements are not included in this document. Advice on such requirements should be obtained from a recognised, qualified source.
2 General

2.1 Scope

These guidelines are applicable to the materials defined in BS 7413 and BS 7722. Due to the wide variety of formulations and profile shapes that exist, it is not possible to describe welding conditions with the precision needed to give maximum weld strength. Consequently, this document should only be regarded as a guide, and further advice, if required, should be sought from the system supplier concerned and from the welding machine manufacturer.

It applies to heat welding only and not to any solvent or other welding methods.

2.2 Definitions

The definitions given in BS 6100, BS 7412, BS 7413, BS 7722, the BPF Code of Practice for the survey and installation of plastics windows and doorsets, (ref. W362/1), the BPF/GGF guidelines for the selection and use of reinforcement (ref 323/1) generally apply.

3 Profiles

3.1 Storage of profiles

Profiles should be stored in accordance with the system supplier's recommendations. They should be stored away from extremes of temperature and should not be exposed to strong sunlight or heat sources such as hot air blowers.

Profiles should not be laid on their rebates or other single point contacts, and should be supported off the ground along their length at no more than 1m intervals to prevent permanent deformation.

3.2 Conditioning prior to use

Profiles should be conditioned prior to sawing and welding for sufficient time for the profile to reach an even, minimum temperature of 15°C in a dry clean environment. Profile should be stored inside for at least 12 hours prior to use.

It is suggested that prior to use the ends of sealed packaging should be opened to facilitate ventilation of the profiles and to help prevent condensation. It is also recommended that any partially used packages which are to be re-stored outside should be re-sealed before being taken outside.

3.3 Sawing

The saw should be capable of achieving the required accuracy of ±15 minutes (0.25°) in the plane of the saw blade and at right angles to it, and shall have sufficient support and clamps to ensure the correct orientation of the profiles when they are being sawn. This should be demonstrated at the time of commissioning by the equipment suppliers.

The saw cut shall be clean with minimal roughness and no discolouration. To prevent contamination of the cut end, the saw used to cut aluminium or steel should not be used to cut
PVC-U profiles. Care should be taken to ensure that any protective film used on the profile does not overlap onto the cut end of the profile, and does not touch the welding plate.

Some profiles may need support, by means of for example contour blocks, during sawing to ensure their correct orientation. It is important to ensure that the profile is properly seated onto the saw bed and that swarf is not causing misalignment.

Loss of accuracy will result in poor quality welds. The accuracy of the cuts should be checked at regular intervals. Annex 2 gives a method for checking the accuracy of sawing.

### 3.4 Storage of sawn profiles prior to welding

To reduce the possibility of damage or contamination, sawn profile should be carefully stored for as short a time as possible in a clean, dry environment at a minimum temperature of 15°C.

Care should be taken to prevent dust gathering on the cut ends of the profile if it is to be stored for any length of time. This can be done, for instance, by storing the profile with the cut ends facing down. When reinforcement is contained within a profile, and this reinforcement has been cut on a saw using suds or other lubricating fluid, this fluid may run off the reinforcement and onto the cut end of the PVC-U profile. This fluid must be cleaned off the reinforcement before inserting it into the profile.

Contamination of the weld by cutting lubrication fluid must be avoided.

### 4 Welding Equipment

#### 4.1 Welder design features and welding principles

A wide variety of welders is commercially available. They range from single head, horizontal plane to multi-headed inclined plane machines. All have the following common welding cycle details:

<table>
<thead>
<tr>
<th>Process sequence</th>
<th>Key variable</th>
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<tbody>
<tr>
<td>Heating and softening</td>
<td>Hotplate temperature (T)</td>
</tr>
<tr>
<td></td>
<td>Axial Pressure (P)</td>
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<tr>
<td></td>
<td>Axial heating length reduction (L)</td>
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<tr>
<td></td>
<td>Heating dwell time (t)</td>
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<tr>
<td>Fusion and cooling</td>
<td>Fusion pressure (p)</td>
</tr>
<tr>
<td></td>
<td>Axial fusion length reduction(l)</td>
</tr>
<tr>
<td></td>
<td>Fusion dwell time (f)</td>
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</tbody>
</table>

T,P and t are significant factors in making a good weld. A value of 30 seconds for t has proven acceptable in practice. With the latest computer operated machines, it is imperative that the parameters described above are clearly identified and controlled.

Other factors which may influence the performance of a weld include materials blend, section size, thermal capacity of the heater plate and ambient temperature.

The welder shall be optimised in accordance with the method given in Annex 1.
It is strongly recommended that initial welding conditions are established on a single head welder in order to identify optimum hot plate temperature (T), fusion dwell time (t) and fusion pressure (p).

Note: Experience has shown that larger and heavier profiles may require different welding parameters than smaller profiles and that separate parameters should be determined by the optimisation procedure in Annex 1.

4.2 Welder location

The welder should be located in a clean dry, environment. It should be away from draughts which may cause cooling of the heater plate which could result in a poor quality weld. There must be adequate space to facilitate the handling of, and supports for larger frames.

4.3 Welder commissioning

The welder should be set up in accordance with the machinery supplier's recommendations. Its cycle should then be optimised in accordance with Annex 1.

Weld tests shall be carried out across the range of profiles to be welded on the machine to demonstrate adequate performance of the welded joints. Any subsequent variations of these initial settings must be followed by repeat weld testing to ensure continued satisfactory performance.

4.4 Contour blocks

Some profiles may require support during the welding process to ensure that the correct orientation of the profiles is maintained and to prevent crushing or distortion of the profile. System suppliers should supply details of the need for, and the design of any contour blocks that may be required. Once set, the adjustment of these blocks should only be carried out by experienced operatives.

Where contour blocks are not used, care should be taken to ensure that the profiles are not distorted by excessive clamping pressure.

4.5 Weld sprue limitation

It is common practice to use heated restrictor knives to limit the size of the weld sprue created during the welding process. Frequently, these are set 1-2mm apart but can be as close as 0.2 - 0.5 mm apart.

Some welding machines have heated restrictors. If so, the temperature of the restrictors should be maintained at the specified temperature, frequently 45-50 °C.

5 Welder operation

5.1 Set-up procedures

Before production recommences at the start of each shift, the following procedures should be followed.

The machinery manufacturer's recommendations for warming up of the heater plates should be followed. A warm-up time of up to 30 min may be required for the heater plates to reach the required temperature. The temperature of the heater plates should be checked at several positions.
over the area used to heat the weldable area of the profile.

The PTFE impregnated sheet covering the welder plate should be checked for:

a) damage - if damaged it should be replaced,
b) colour - heavy discolouration is an indication that the cover is old and is due for replacement.
c) contamination - the cover should be free of contamination. Light contamination can be removed by the use of a tissue or similar (beware burns!). Severe contamination necessitates replacement of the cover.

It is essential to ensure that any covering tape on die profile does not contaminate the weld. This can be ensured by, for example, peeling the tape back prior to welding.

The temperature and gap of the restrictor knives should be checked and adjusted if necessary. A visual check is also necessary to ensure that the knife edges are free from damage, burrs and contamination.

The physical condition of any contour blocks should be checked to ensure that there is no damage and that they are seated properly on the welder.

The cycle times and pressures of the welder should be checked to ensure that they are set to the pre-determined optimum conditions and changes should only be made by suitably trained personnel.

The configuration of the welding heads on multi-head machines should be checked to confirm that it is suitable for the styles to be manufactured.

The initial weld from each production welder should be visually assessed for acceptability of appearance. During the course of production, sample welds should be made and tested in accordance with the Quality Plan.

6 Weld quality

6.1 General

The quality of the weld is determined by visual assessment, weld strength testing and process control.

6.2 Visual assessment

A weld shall be deemed to be visually acceptable provided that it appearance is:

- square
- free from contamination
- free from bubbles in the sprue
- with uniform sprue of the desired size and form
- free from discolouration (white profiles only)
- free from cracks.
6.3 Physical testing

Physical testing of fully finished welds (see section 7) should be carried out regularly, preferably by the method described in BS 7413:2002, Annex I, or by any other method which can demonstrate consistency of weld performance.

6.4 Routine verification of process conditions

Certain routine inspections will increase the likelihood of consistently high weld quality including:

a) the verification at frequent intervals, by means of, for instance, hand held quick response surface contact temperature gauges with low thermal mass antennae (hand held digital thermometers), that the surface temperature of the hot plates is within the prescribed limits;

b) checking that the clamping and axial pressures and the heating and fusion times are within the limits determined by the optimisation procedures given in Appendix 1;

c) critical examination of the corner welds including checking the final frame size.

Note. Final frame sizes can be affected by the mitre saw settings.

7 Weld finishing

After welding the joint will require further processing to improve its aesthetic appearance. These processes include:

a) feature grooving - this is the process whereby the weld sprue is removed from the welded joint line and a shallow groove remains;

b) polishing - this entails the removal of the weld sprue by abrading and polishing the joint until it is level with the profile surface;

c) knifing - surplus plastic is removed using a sharp purpose-made knife or cutter. Care must be taken not to damage the adjacent profile.

Note 1. Weld finishing will result in the reduction of the strength of the corner. Poor weld finishing will further reduce the strength.

Note 2. Sharp chisels are frequently used to remove surplus plastic from the inner surface of the welded joint. Great care must be exercised in this procedure to avoid cutting into the profile surface. Failure to do so could cause stress concentration and premature weld failure.

8 Factory floor assistance

A summary sheet is shown in Annex 3 which may assist a welder operator in correct use of the machine. It is not intended for use as a formally controlled document.

It is available separately in plastic coated form reference numbers 333/1 for A4 size and 334/1 for A3 size.
Annex 1 Welder optimisation

A.1 The system supplier will have carried out a detailed evaluation of welding conditions for each main profile, and the procedure now described is, therefore, primarily intended as guidance for fabricators when setting up multi-head welders.

A.2 Check the tolerance of the operating temperature gauge setting. Using a good quality quick response surface contact temperature gauge placed against the heating blade at several points which would normally be in contact with the profile during welding, take temperature readings as the blade heats up and cools down. Note the maximum and minimum temperatures and the time taken to reduce from maximum to set temperature after the heater switches off. When checking future temperature settings, measurements should be made after a similar time period, and test welds should also be made after the same interval from heater switch off. Temperatures should not fluctuate more than ±5°C from those set.

A.3 Adjust the welder to the following nominal settings:

1.75 Bar fusion pressure (p)
25s Heating dwell time (t)
255°C hot plate temperature (T)

Make a minimum of 3 weld samples. Repeat the process for temperatures at steps of 5°C down to 220°C.

After at least 4 hours standing time, physically test all corner samples and plot the average results. Determine the optimum hot plate temperature (T).

A.4 Adjust the welder to have nominal settings of:

1.75 Bar fusion pressure (p)
Optimum hot plate temperature (T), previously determined, or a nominal 235°C.
10 s heating dwell time

Make a minimum of 3 weld samples. Repeat the process at 5 second heating dwell time increments to 45 seconds.

After at least 4 hours standing time, physically test all corner samples and plot the average results. Determine the optimum heating dwell time (t).

A.5 Adjust the welder to have nominal settings of:

Optimum hot plate temperature (T) previously determined, or a nominal 235°C.
Optimum heating dwell time (t) previously determined, or a nominal 25 s.
1 Bar fusion pressure.

Make a minimum of 3 weld samples. Repeat the process at 0.5Bar fusion pressure (p) increments up to 3.5Bar. Check that at no time are the profiles sliding under the clamps.

After at least 4 hours standing time, physically test all corner samples and plot the average results. Determine the optimum fusion pressure (p).

A typical optimisation result is shown in Fig 1.

A.6 Having determined the optimum conditions, weld 5 corners at these conditions. After at least 4
hours standing time, physically test all the samples to verify adequate weld performance.

It is recommended that similar data is obtained for each main frame profile.

For larger profiles, e.g. door sashes, a higher value of axial pressure, P, is required in direct proportion to the increased weight of these profiles in relation to those used when optimising the welder. Advice should be sought from the system supplier.

The above procedure assumes that dimension stops, angular alignment and sprue limiters are correctly adjusted. If in doubt, the equipment supplier should be contacted and any necessary adjustments made before the procedures described are followed.

To optimise conditions for multi-head welders, the technique described above, designed to optimise conditions for a single head welder, can be used with test samples being produced as welded rectangles permitting samples for physical assessment to be cut from them.

In the case of both 2 and 4 headed welding machines the rectangular test frames should produce rectangles without bow or sag in any of the sides. Such bow or sag would indicate that the mitres have been incorrectly cut or the heater plates incorrectly set. It is essential that corrective adjustments are made to the equipment prior to optimisation, as stressed welds will be made resulting in lower performance.

Note: The centre welding head of 3 headed welding machines is usually fitted with a centre heating plate which comprises two heating elements at 90° to each other. This plate is used to make transom or mullion joints and for cruciform joints. To prevent the bowing of the frame at this point, it is essential that sprue limiters are correctly adjusted and that the transom/mullion length is cut with the correct allowance for the creation of the welding sprue.

![Graph of typical optimisation result](image-url)
Annex 2 Accuracy of sawing

Accurate sawing is important for three fundamental reasons:

(i) for correctness of length;
(ii) for correctness of angle;
(iii) for squareness of cut.

The accuracy of the cut with respect to length is vital to avoid the transom and mullion problems mentioned in Annex 1, and with respect to angle to ensure that frames and vents form perfect rectangles.

A profile which is imperfectly extruded and which has major faces which are not square to each other (i.e. lack of parallelism) may not cut squarely. Gross examples of such imperfections occur when the length of a transom/mullion may differ by more than 1mm when measured on opposite surfaces of the profile.

A dry assembly of an outer frame is recommended to check angles and gaps. The dry assembly is carried out by positioning the cut profiles on a flat surface prior to welding in the intended position (i.e. at 90° for a normal corner) and measuring any resultant gaps on both the upper and lower surfaces (see figure 2).

The check takes only a few minutes to complete and can be developed to suit any Quality Plan. The recommended maximum tolerance is 0.5mm per side, i.e. a maximum total gap of 1mm.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Variation(mm)</th>
</tr>
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<tbody>
<tr>
<td>30</td>
<td>0.52</td>
</tr>
<tr>
<td>40</td>
<td>0.70</td>
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<td>50</td>
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<tr>
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<tr>
<td>70</td>
<td>1.22</td>
</tr>
<tr>
<td>80</td>
<td>1.40</td>
</tr>
</tbody>
</table>
Figure 2. Dry assembly of corner joint
Annex 3 Summary sheet

SUMMARY SHEET
for welding PVC-U profiles

Conditioning
Have profiles been stored inside for at least 12 hours to allow them to reach the required temperature?
Are the cut profile surfaces free from dust, moisture and reinforcement cutting fluid?

Welding
Are the optimum conditions known for the profile to be welded?
Is the welder located away from draughts?
Are profile contour blocks to be used?
Are weld sprue limiters set correctly? 40 - 45°C, 2mm apart.
Has the welder had sufficient time to warm up?
Check that the PTFE tape is not
- damaged
- discoloured
- contaminated

Machine Process settings
Are the following parameters set to the optimum levels?

T hot plate temperature °C
P axial heating pressure Bar
L axial heating length reduction (burn-off) mm
t heating dwell time s
p axial fusion pressure Bar
l axial fusion length reduction mm
f fusion dwell time s
Clamping pressure bar

Weld quality
Visually assess the weld
- squareness
- uniform sprue
- free from contamination
- free from bubbles
- free from discolouration
- free from cracks

Physical testing
Have comers been tested in accordance with the Quality Plan?