LEISTER®

Optimum Welding Parameters for Leak-proof Flat Roofs

EXPERTISE | Practical Knowledge for PVC and TPO Membranes



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Management Summary

Starting Point

Waterproofing flat roofs with plastic membranes has been a tried and tested technique for decades. Whether it's industrial or pitched roofs, structures that were once purely protective have developed into utility roofs. This not only extends the service life of the roofs but also makes an important contribution to sustainability.

A permanently leak-proof roof is essential, and setting correct welding parameters plays a critical and integral role.

Aims

This expertise provides the welder with a method for determining welding parameters, bringing specific construction site conditions into consideration. It includes practical knowledge on various geomembranes such as PVC and TPO for machine and manual welding, as some users are uncertain about which welding parameters to set. Video sequences illustrate the transition from manual to machine welding and show how the quality of the seam joint can be evaluated and checked. The aim is to provide a basic understanding of the professional processing of various plastic membranes.

Analysis

The approach to setting the correct welding parameters is sometimes unclear, especially for inexperienced installers and welders. The tendency is to set temperatures that are too high in the belief that higher temperatures are better. However, this leads to plastic molecules being destroyed, resulting in leaks or poor seam connections.

Recommendations

Expertise and experience are always a prerequisite for installing and welding plastic membranes. Ideally, the installer should attend a basic plastic welding course to enhance the knowledge gained during practical jobsite experience. A variety of training courses are offered by material and equipment manufacturers, helping create a solid foundation of knowledge and skill.

Processing and joining plastic membranes is not rocket science – provided the basic rules are followed. This includes assuring clean seams and setting the right welding parameters through test welds, adapted to the plastic membrane being joined.

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1. Introduction: Sustainable Commercial Roofs with Permanently Leak-proof Seams

Flat roofs – whether industrial or private – are exposed to heavy loads. It is therefore essential that membranes are joined using the correct welding parameters. A prior test weld and the proper assessment help assure joining quality.

To meet the requirements for waterproofing flat roofs for private and industrial use, material manufacturers, experts, and roofers face the following challenges:

- How can it be ensured that correct welding parameters are used for joining?
- How can it be ensured that temperatures are not set too high during welding?
- What is the approach to test welding and its correct assessment?
- What should be considered when preparing the seam?
- What should be considered when switching from machine to manual welding?

This expertise answers key questions from the field and offers tips and tricks – as a comprehensive guide for high quality plastic roof membrane installation.



2. Setting Correct Welding Parameters

Most material manufacturers offer guidelines or specifications that define starting parameters for their products. The parameters are relevant whether using manual welders or automatic welding machines. It is important that the initial parameters align with the respective material type, as welding parameters can differ significantly depending on the combination of material type and welding machine used.

The origin of the parameter specifications should always be considered, as modern plastic welding machines often have pre-installed initial parameters in the device software which can be activated and adjusted depending on the material type – such as PVC or TPO.

Please note: These parameters are only generic basic settings. Individual adjustments must be made depending on the manufacturer and the specific material properties.

In addition to a visual assessment of a welded seam, the operator must also conduct a precise physical inspection in order to assess it correctly. The results of this inspection show how the welding parameters can be specifically adjusted to achieve a permanently leak-proof joint. It's important to understand that changing the temperature and speed at the same time may not achieve the desired result.

Because the effects of multiple parameter changes cannot be clearly delineated, the operator should only adjust one parameter per test weld. This allows the change in welding quality to be tracked clearly and specifically optimized.

Certain plastics, such as membranes made of PVC, TPO, FPO, EPDM, PIB, EVA, ECB, or HDPE, tend to change negatively at high welding temperatures. These changes can harm the welding quality or even lead to leaks that are often not visible to the naked eye.

Welding parameters recommended by material manufacturers and equipment suppliers are often specified as a range, for example 450 °C–520 °C / 2.5 m–3.5 m / min (842 °F–968 °F / 8.20 ft –11.48 ft/min) and 100 % air. Start the tests with average values, for example 480 °C / 3.0 m/min (896 °F / 9.84 ft/min), 100 % air, and adjust as required. Change only one parameter at a time (temperature or speed) and test again until the desired result is achieved.

Plastic Membranes

There are various types of robust plastic membranes that differ in terms of material, properties, and application. The most common types are: PVC, TPO, FPO, EPDM, PIB, EVA, ECB, HDPE.

Differences between PVC and TPO/FPO

Fundamentally, it is important to know which thermoplastic material will be joined. The following rules of thumb apply to the main groups:

Material type	Setting the temperatures	Special observations
PVC	Compared to TPO/FPO, higher temperatures tend to be set.	When joining at excessively high temperatures, brown discoloration occurs first, followed by slag formation.
TPO/FPO	Temperatures tend to be set lower than PVC.	There are PE-based membranes that require significantly higher temperatures. When welding at significantly high temperatures, a noticeable shine appears in the welding area at first, then, varying sized blisters form – a clear sign of an overheated connection.

This basic knowledge helps the welder set the correct initial parameters for the test weld.

Material selection criteria

The decision between choosing TPO and PVC membranes depends on the market. The following factors must be considered:

- Climatic conditions (temperature resistance, UV stability)
- Budget (material and processing costs)
- Chemical resistance (e.g. to oils, greases, acids)
- Mechanical properties (flexibility, welding behavior, long-term performance)

A precise analysis of environmental conditions and technical requirements is essential when choosing between TPO and PVC membranes.

High humidity does not necessarily have a negative effect on weld quality. However, it becomes problematic when membranes or welding equipment absorb moisture, for example due to long periods of storage in high humidity (three days or longer) or if they lie in water. This can cause blistering or open welding points. Clean, dry and protected membrane storage is therefore essential to avoid processing flaws.

Standard Values for Welding Parameters

Below you will find new, generic guide values as starting parameters, empirically determined by Leister based on the latest findings. The guide values are to be understood as recommendations and must be verified by test welds.

Standard values for initial welding parameters in Europe

Machine welding VARIMAT 700/500, 400 V

Material	Temperature (°C)			Speed (m/min)			Air flow (%)	Additional weight (kg)
	min.	Ø	max.	min.	Ø	max.	18000 RPM	
PVC	500	530	560	2.2	3.5	4.0	100	3
FPO/TPO	400	480	540	2.5	4.5	5.0	100	3
EPDM modified	520	560	600	2.5	3.5	4.0	100	3
EVA	450	520	550	2.5	4.0	4.5	100	3
PIB	450	500	550	2.5	3.5	4.0	100	3
ECB	500	540	580	2.5	3.0	4.0	100	3

Standard values for VARIMAT 300 and device version 230 V, 20 cm/min slower in speed, temperatures remain the same.

Machine welding UNIROOF 700

Material	Temperature (°C)			Speed (m/min)			Air flow (%)	Additional weight (kg)
	min.	Ø	max.	min.	Ø	max.	18000 RPM	
PVC	500	540	560	1.6	2.5	2.8	100	2.5
FPO/TPO	400	480	540	2.0	2.7	3.5	100	2.5
EPDM	520	560	600	2.0	2.2	2.5	100	2.5
EVA	470	520	570	2.0	2.5	3.0	100	2.5
PIB	450	500	540	2.5	3.0	4.0	100	2.5
ECB	500	540	580	2.0	2.5	3.0	100	2.5

Standard values for UNIROOF 300 and device version 230 V, 20 cm/min slower in speed, temperatures remain the same.



Machine welding UNIDRIVE 500

Material	Temperature (°C)			Speed (m/min)			Air flow (%)	Additional weight (kg)
	min.	Ø	max.	min.	Ø	max.	18000 RPM	
PVC	460	480	540	1.6	1.8	2.8	100	–
FPO/TPO	380	400	440	1.6	2.0	2.5	100	–
EPDM	520	560	580	1.7	1.8	2.0	100	–
EVA	400	420	450	1.5	1.8	2.0	100	–
PIB	400	420	450	2.0	2.5	3.5	100	–
ECB	480	520	560	2.0	2.2	3.0	100	–

Manual welding TRIAC AT

Material	Temperature (°C)			Speed (m/min)			Air flow (%)	Additional weight (kg)
	min.	Ø	max.	min.	Ø	max.	18000 RPM	
PVC	340	380	430	–	–	–	100	–
FPO/TPO	260	320	360	–	–	–	100	–
EPDM	500	520	580	–	–	–	100	–
EVA	360	380	430	–	–	–	100	–
PIB	350	400	450	–	–	–	100	–
ECB	500	520	580	–	–	–	100	–

Standard values for initial welding parameters in the USA

Welding parameters for materials of the same type may vary depending on the region of origin (USA, Asia or Europe). This is due to the varying legal standards for material composition in these regions.

Machine welding VARIMAT 700/500, 230 V

Material	Temperature (°F)			Speed (ft/min)			Air		
	min.	max.	rec.	min.	max.	rec.	min.	max.	rec.
TPO	842	1004	986	12.1	18.0	14.7	100 %	100 %	100 %
PVC	932	1022	1004	9.8	16.4	13.4	100 %	100 %	100 %

Standard values for VARIMAT 300, 7.87 in/min slower in speed, temperatures remain the same.

Machine welding UNIROOF 700, 120 V

Material	Temperature (°F)			Speed (ft/min)			Air		
	min.	max.	rec.	min.	max.	rec.	min.	max.	rec.
TPO	842	1022	986	7.2	9.8	8.2	85%	100%	100%
PVC	950	1040	1022	5.9	9.8	7.8	85%	100%	90%

Standard values for UNIROOF 300, 7.87 in/min slower in speed, temperatures remain the same.

Machine welding UNIDRIVE 500, 120 V

Material	Temperature (°F)			Speed (ft/min)			Air		
	min.	max.	rec.	min.	max.	rec.	min.	max.	rec.
TPO	932	1022	986	3.9	6.5	4.9	100 %	100 %	100 %
PVC	932	1022	1004	4.9	6.5	4.9	100 %	100 %	100 %

Seam Preparation

1. During membrane installation, roof workers should minimize foot traffic and avoid placing objects within the areas to be welded.
2. Contaminated membranes must be thoroughly cleaned before welding to remove all residues. Clean white cloths and a mild cleaner are suitable. Cleaning should always be performed according to the respective supplier's specifications. Before welding, the membranes must be clean, dry, and free of grease. While new and clean membranes do not typically require cleansing, some membranes require pre-treatment to remove oxidation.
3. Repeatedly stepping into or placing objects in the overlap area will lead to contamination. The area must be cleaned before welding, otherwise it can lead to poor weld seams or leaks.
4. In addition, avoiding membrane contamination wherever possible saves from incurring additional labor cost while facilitating high-quality welding.
5. Welding work should only be performed when dry, since moisture can impair seam quality and lead to leaks. However, if welding is conducted in the rain, the seams must be checked thoroughly later and any leaks repaired according to manufacturer specifications.



Watch video

Procedure for Dirty Membranes

Contaminents such as leaves and branches can be removed with a broom or blower, while loose dirt, such as drilling dust, is best removed with a broom or a dry cloth. Water and a soft brush are sufficient for solid dirt, however coarse brushes or steel wool should not be used to avoid potential surface damage.

For stubborn dirt or stains, a special cleaning agent recommended for PVC or TPO roofs by the material manufacturer can be used. These products are generally suited to the material, clean reliably and protect the surface at the same time.

Many manufacturers test their cleaning agents themselves and offer suitable products. However, if alternative cleaners are used, there is a risk of defective weld seams – even if they appear visually perfect. Since formulations differ by membrane manufacturer, choosing the appropriate cleaning agent is essential. Chemical cleaners must also be allowed to evaporate completely in order to avoid residues that could affect seam quality.

The roof must be clean, dry and free of grease to ensure proper welding. During cleaning, cracks, holes, or leaks should be detected and repaired immediately to prevent consequential damage.

Solvent

Only cleaners approved by the membrane manufacturer may be used.

The use of commercially available, aggressive cleaning agents or solvents, such as acetone, is prohibited. These substances can alter or damage the chemical structure of PVC, TPO, and FPO membranes.

Solvents must be used in accordance with the membrane manufacturer's instructions. Care should be taken to use the product sparingly to avoid liquid accumulation on the membrane, as this can negatively affect the material properties. White cleaning cloths are preferable as they do not cause color transfer to the membrane.

After applying a solvent, the full evaporation time specified by the manufacturer must be observed in order to avoid residues that could impair welding quality.

Oxidation layer on FPO and TPO membranes – Influence on welded joints and recommended measures

FPO and TPO membranes can develop an invisible oxidation layer during storage caused by humidity or environmental influences.

This oxidation layer can appear in the form of microscopic deposits or spots that are invisible to the naked eye.

The oxidation layer can significantly impact weld seam strength and lead to leaks or inadequate welds that jeopardize the function of the sealing system. Such damage often goes unnoticed for a long time and may only become apparent after two years or more.

Process for removing the oxidation layer

There are two proven methods for safely removing the oxidation layer:

- Chemical cleaning with special solvents. The use of special solvent-based cleaners facilitates effective removal of the oxidation layer. This method has the disadvantage of being less environmentally friendly and may cause emissions-related environmental impacts, depending on the solvent used.
- The scraping nozzle is a mechanical solution that effectively removes the oxidation layer by grinding the surface. This method is compatible with almost all FPO and TPO membranes and is considered an environmentally friendly alternative to chemical cleaning. For the best welding results, the use of an additional weight is recommended with this method to ensure a uniform and secure joint. Physical oxidation removal is particularly suited to projects with high sustainability requirements.
  Important: This technique is used exclusively to remove oxidation and is not suitable for removing dirt or other impurities.



Example of a scraping nozzle

Suitable Welding Equipment and Accessories

Suitable welding equipment such as manual hot air welders, automatic welding machines and the right accessories (e.g. shears, knives, pressure rollers, nozzles and electric cables) are essential for high-quality welded joints. The equipment used must be in perfect condition and regularly maintained to ensure consistently high processing quality.

Devices with digital temperature displays are highly recommended. Both membrane and equipment manufacturers prefer this design as it enables continuous, electronic monitoring of welding parameters. Welding devices without a digital temperature display can have considerable deviations in the hot air temperature settings, which may have a negative effect on welding quality.

Analog devices react sensitively to various external influences. Factors such as ambient temperature, mains voltage fluctuations (undervoltage or overvoltage), electrical connections (plugs), cable length, and insufficient wire cross-sections can have a considerable impact on the welding parameters. It is possible that several of these factors can interact and lead to a deviation of over 100 °C / 212 °F from the set temperature. To avoid this, only cable connections and extension cables with a minimum wire cross-section of 2.5 mm / 0.098 in should be used.

For analog devices (without a temperature display), it is also recommended to conduct regular temperature checks with an external measuring device. Only approved and tested test equipment should be used, as unsuitable test devices can lead to inaccurate results.

Welding machines

Regular welding machine maintenance and servicing is critical to achieve a long device service life and optimum welding results.

All visible components should be checked for wear or damage at regular intervals, including housings, cables, hoses, nozzles, pressure rollers and heating elements.

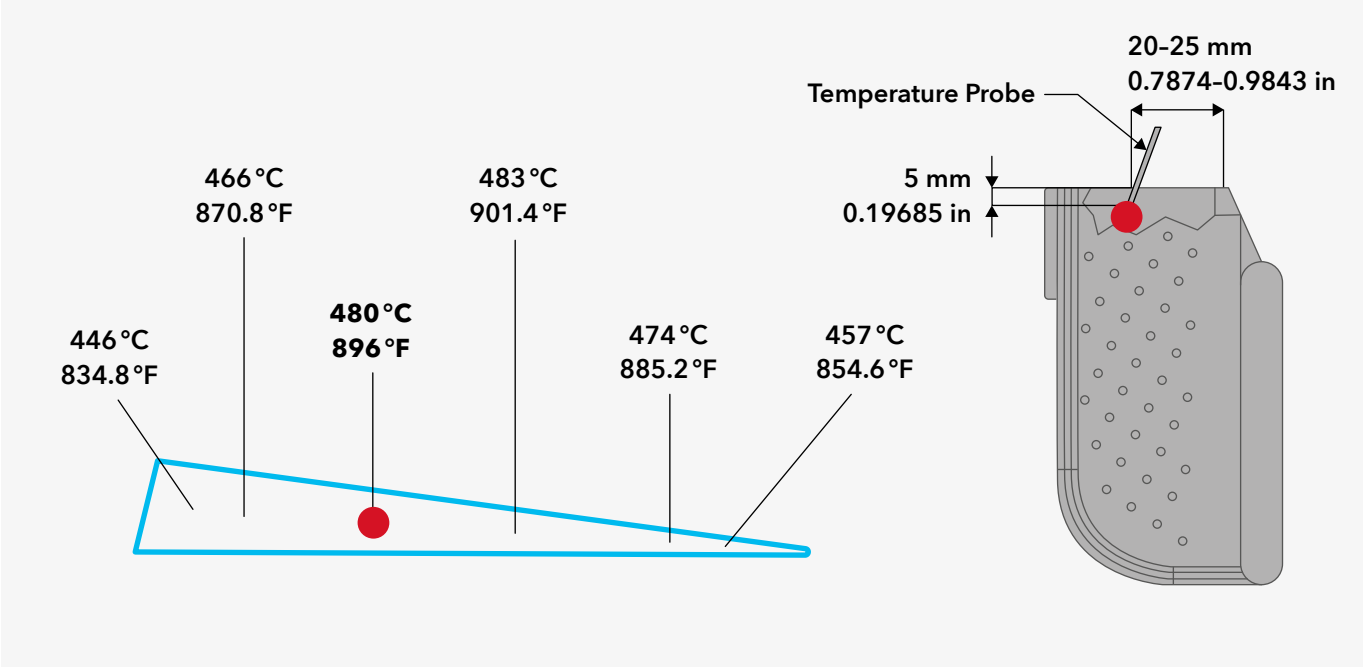


Damaged nozzle

Watch video

The hot air tool temperature must be regularly checked to ensure it remains constant.

A deviation could indicate a problem with the heating element or the temperature control/ temperature probe.



Temperature reference measuring point

Hand-held devices

The device should be comfortable to hold, especially when used for long periods. When assessing ergonomics, weight is frequently a key consideration. Depending on the application, different device variants are available, including tool size, models with external air supply, as well as those with varying output. A wide range of accessories are available for welding machines and hand-held devices. The correct use of suitable accessories such as nozzles and pressure rollers is critical, as wrong combinations can lead to welding defects, material damage, or leaks.

Pre-welding, also known as two-pass welding, is often recommended when using a 40 mm nozzle. The assumption that pre-welding can be omitted in the case of larger nozzle sizes poses risks for the seam quality and should be avoided. The responsibility for a professional and leak-proof welded joint remains with the personnel conducting the work.

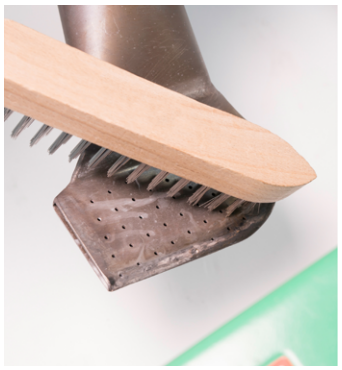
Watch video

Maintenance

Clean all device air filters frequently to prevent overheating, which can reduce welding quality and cause open seams.

Nozzles should be checked regularly for damage, bending, or blocked ventilation slots, as these can also lead to overheating or insufficient welding. Nozzles and air ducts should be cleaned to remove dirt deposits, which can negatively impact quality and result in leaks.

All welding machines should be routinely serviced by trained personnel to ensure proper functioning and confirm the accuracy of temperature, speed, and air volume settings.







To ensure that welding seams remain leak-proof and resilient as long as the membranes themselves, good maintenance and care of the devices is critical.

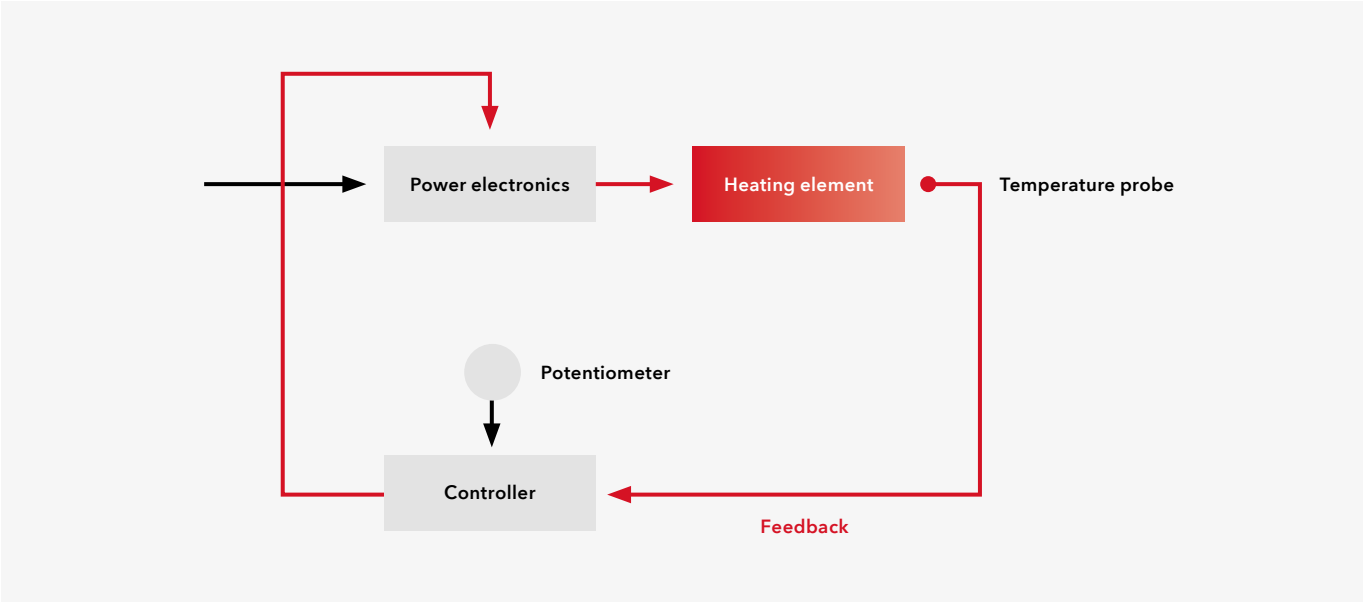
Storage

If the welding machine is not in use for an extended period of time, it should be stored in a dry and dust-free location. Make sure that no heavy objects are placed on top of the device that could damage it. A test run must be performed after every maintenance, service, or repair interval to ensure the device is functioning properly.

Advantages of closed-loop welding machines

Hand-held devices with analog temperature control are inexpensive, but less precise and prone to greater temperature fluctuations. The user needs significant experience and routine training to get optimum performance from the device.

The use of hand-held devices with digital temperature control is therefore recommended, thus ensuring consistent temperature and enabling precise and reliable welding.



Modern welding machines should be equipped with software and hardware to control the welding parameters. The parameters are set on the controller. The temperature probe (hardware) then checks the set temperature. As soon as the temperature is reduced due to undervoltage, the temperature probe sends a pulse to the power electronics (software). The software control then ensures that the welding parameters remain constant despite undervoltage of up to a maximum of 20 %.

Procedure for Test Welds

Choice of material

The materials utilized for test welding must be the same as those specified for use in the project.

All manufacturer specifications and respective installation instructions must be followed.

Watch video
TPO membrane

Watch video
PVC membrane

Welding parameters
Various procedures are available for determining appropriate start parameters.

It is recommended that no welding be conducted if the ambient temperature is below –5 °C / 23 °F or above 35 °C / 95 °F. If the ambient temperature is outside this range, special measures must be taken as per the manufacturer's instructions.

Watch video

Testing the welded seam
After the welding process, the joint must be allowed to cool completely (at least 5 minutes for PVC, 15 minutes for TPO/FPO) before a tensile strength test can be performed on the welded seam. This allows the connection force to be reliably tested. The seam should be firm and not show any signs of detachment. For a more precise assessment, cut and remove welding samples around 2 cm/1.0 inch wide from across the seam (cross-peel examination), taking at least two to three samples from different areas of the membrane. The start and end points of an automatic welding seam must also be checked carefully.

Watch video

Additional visual and tear test
It is recommended to perform a series of cuts along the weld seam at distance intervals of around 1 cm or 3/8 in each and peel back along the joint seam. This sometimes reveals that the entire welding width is not optimally welded, which can lead to voids. If welding temperatures are too high, burns can occur at the beginning or end of the welding seam, which can result in leaks.

Three good welds

A precise test procedure is required for every new project or when changing the membrane. Several test welds are usually necessary to determine appropriate welding parameters. After checking all test welds, there should be at least three perfect welding seams representing different parameter settings. It is recommended to select the median setting to ensure a permanently leak-proof weld in normal weather conditions. On subsequent workdays, a single test weld is usually sufficient. Multiple test welds are only required for recalibration in cases of significant deviations or suspected leaks.

Visual inspection
During the visual inspection, each weld seam must be checked for an even, smooth surface – free of cracks, bubbles or air pockets. The seam layers must be fully and completely bonded to each other and must meet the requirements for tightness, mechanical strength, and durability. The appearance of a properly evaluated test weld should be documented and used as a reference for future evaluations.

Assessment of welding characteristics

Shine next to the weld seam:

- Yes, document the width of the glossy zone
- No, no shine or only slightly visible shine

Bead along the weld seam (material flow or bleed out):

- None visible
- Visible: Document size
- Only briefly visible after the pressure roller

Membrane discoloration around the weld:

- In most cases, this is an indication of insufficient weld quality.

Shiny appearance on the upper membrane in the welding area:

- This is usually a sign that the welding temperature is too high and should be considered a negative result.



Watch video

Quality assurance while welding

By closely monitoring the roll installation sequence during the project, you can evaluate and assess the welding as it progresses. This allows quality to be improved, and potential errors to be identified and rectified at an early stage. It is important to allow the welding seam to cool and harden completely after welding.

- Regular tests and inspections during the processing of plastic roof membranes are essential to ensure long-term quality standards.
- **Documentation:** All test results and welding parameters (temperature, speed, pressure, air percentage), as well as the date, weather, name of welder and tester must be carefully documented. Some modern welding machines possess technologies that record welding data, allowing users to analyze information for improving quality management during the project, then create project archives for future reference.

The myLeister app generates a simple and automatic welding log.

- **Additional controls for automatic welding seams:** The operator should also check the starts and stops of automatically welded seams before completing the seam manually. Poor welds can therefore be detected at an early stage and the parameters adjusted if necessary.
- **Metal plate for seam optimization:** Inserting a metal plate at the start and end points of an automatic welding seam makes subsequent checking and manual finishing easier. This increases the quality of the welding seam and ensures a clean transition.



Watch video

3. Transitions from Machine to Manual Joining Seams

Transitions from machine welding to manual welding are potential sources of error, however, with the right procedure, these transitions can be made reliable and permanently leak-proof. Hand welders are suitable for such applications. Choosing the right nozzle and pressure roller makes the welding process much easier and contributes significantly to a clean and high-quality welding result. To avoid problems, care should be taken to ensure that the transitions are not welded at an excessively high temperature.



Watch video

4. Conclusion

Welding plastic membranes is fundamentally simple – however, careful seam preparation and precise test welding are critical to achieve permanently leak-proof and durable weld seams.

The quality and longevity of weld seams are greatly influenced by operator experience and the deliberate fine-tuning of welding parameters. Weld seams initiated by machine and completed manually must be expertly joined to guarantee system-wide leak tightness.



Glossary and List of Abbreviations

Term	Explanation
ECB	Roofing membranes and liners made from ethylene copolymer bitumen
EPDM	EPDM is an acronym for ethylene propylene diene monomer rubber.
EVA	Ethylene-vinyl acetate copolymer
PIB	Polyisobutylene (PIB) is the name for a thermoplastic polymer made from isobutylene.
PIR insulation	The abbreviation PIR stands for polyisocyanurate – sometimes known as polyiso rigid foam.
PUR insulation	PUR rigid foam thermal insulation materials are closed-cell rigid foam plastics made of polyurethane.
PVC	Polyvinyl chloride is a thermoplastic polymer produced by chain polymerization from the monomer vinyl chloride.
SIA	Schweizerischer Ingenieur- und Architektenverein (Swiss Society of Engineers and Architects)
TPO/FPO	TPO (thermoplastic polyolefins) and FPO (flexible polyolefins) are essentially the same material for roof waterproofing. The difference is that some manufacturers sell their TPO products under the name FPO because they are less rigid than other polyolefins. TPO/FPO membranes are made from an alloy of different plastics, such as polypropylene, polyethylene and polybutylene, most often used for low-slope roof waterproofing.

Sources

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