9 Welding polyolefins

9.1 General

Plastic can be welded with various welding techniques, although not every welding method is suitable for the welding of polyolefins. In designing a plastic pipe system, it is therefore important to obtain information about possible welding techniques and their applicability as early as the planning phase. The choice of the most appropriate welding procedure is usually influenced by following factors: economics, the construction of the component, external and internal influences on the system, as well as local conditions.

Figure 9.1 shows the welding practices most frequently used with plastics. The grey highlighted frames indicate the welding techniques usually employed for the welding of PE in plastic pipe construction. In practice, the welding methods most frequently used to connect PE pipe components are butt-welding and electrofusion.

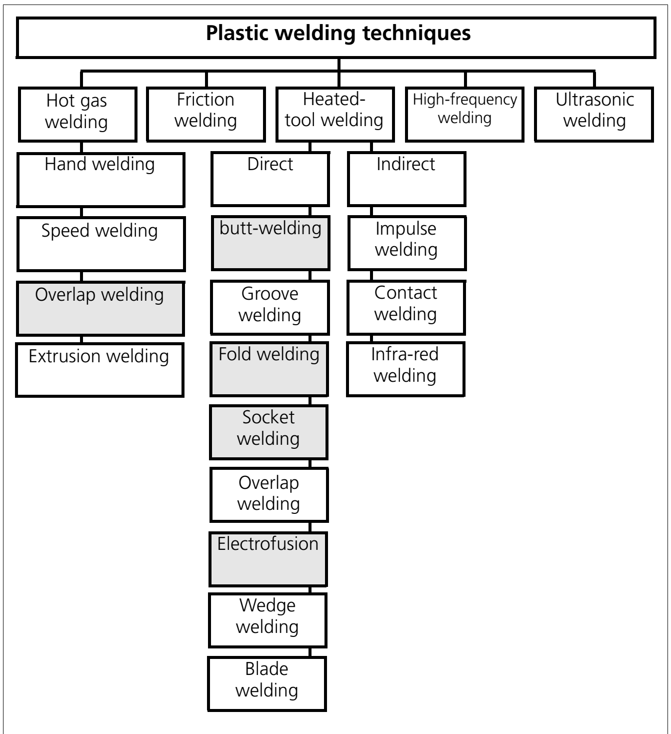


Figure 9.1 Welding techniques

9.2 Welding procedures

9.2.1 Socket welding

Description

Socket welding (also known a polyfusion) resembles butt-welding in its technique. The process is described in detail in the guidelines of DVS 2207 Sections 1, 5 and 11 with respect to the relevant plastic being used. In socket welding, both the spigot and socket are simultaneously heated. After ending the heating process, the socket is shoved over the spigot and pressure applied. The difference from butt-welding consists in the fact that the joining surfaces are connected in an overlapping manner. Therefore, one side of the heating element possesses a form on which to mount the socket (heating spigot) and the other side a form into which to plug the spigot (heating socket), see figure 9.2.

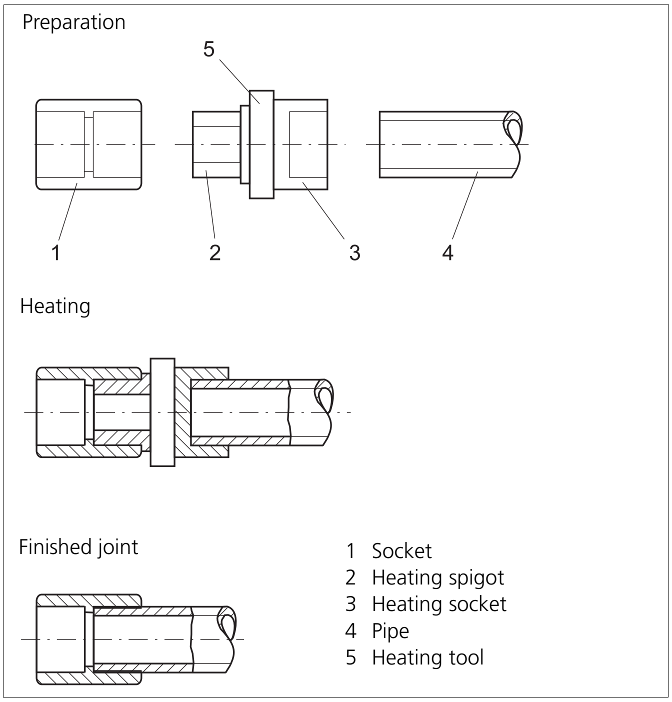


Figure 9.2 Socket welding

The sizes of the heating element and the elements to be welded conform to each other to the extent that the joining of the elements creates a welding pressure. Welded pipes up to a diameter of 50 mm can be welded by hand, larger diameters up to and including 110 mm must be welded with the aid of an apparatus.

Socket welding process - preparation

In principle, the areas corresponding to the welding seam must be carefully prepared, as faultless quality and leak-tightness can only be guaranteed when the joining surfaces are appropriately pre-treated. For this reason, the following rules for preparing the welding surfaces in pipe construction have a great deal of importance and should always be complied with:

- The welding surfaces are to be mechanically prepared immediately before the welding process using a scraper, grater or peeler in order to remove the oxidation layer.
- The spigot is to be bevelled as indicated in table 9.1. Figure 9.3 shows a properly bevelled spigot.
- The connecting surfaces of the pipes or fittings are prepared according to manufacture information.
- Bumping the end of the pipe against the floor of the heating tool to be avoided.
- In welds performed without machinery, the insertion depth equal to distance (E) in table 9.1 must be marked on the pipe.
- The joining surfaces must be free of grease and dust. The socket must be thoroughly cleaned on the inside and the spigot on the outside using a degreasing agent (e.g. industrial alcohol) and absorbent, non-fraying and uncoloured paper. The same applies to the heating element.
- The work site should be arranged so that there are areas in which welding can occur independent of atmospheric conditions.
- No welding work can be performed when ambient temperatures are under +5°C without taking special measures (e.g. protection by a heated tent). The temperature in the immediate proximity of the welding location should not vary more than 10°C during the welding procedure.
- The functional capacity of the machines and equipment has to be tested prior to welding. In particular, the welding parameters need to be checked. For PE the temperature of the heating element is 250-270°C.

Welding polyolefins

Pipe diameter d_e (mm)	Pipe phase b (mm)	Insertion depth E (mm)
16	2	13
20	2	14
25	2	15
32	2	17
40	2	18
50	2	20
63	3	26
75	3	29
90	3	32
110	3	35
125	3	38

Table 9.1 Weld preparation phase for pipe ends

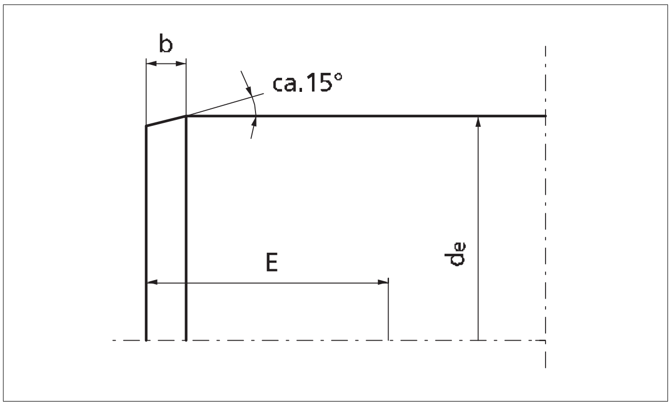


Figure 9.3 Pipe phase in socket welding

1 Outside pipe diameter (mm)	2 Heating SDR 11	SDR 17	3 Conversation (maximum time) (s)	4 Cooling fixed (s)	5 Cooling total (min)
16	5		4	6	2
20	5		4	6	2
25	7	(1)	4	10	2
32	8	(1)	6	10	4
40	12	(1)	6	20	4
50	12	(1)	6	20	4
63	24	(1)	8	30	6
75	30	15	8	30	6
90	40	22	8	40	6
110	50	30	10	50	8
125	60	35	10	60	8

(1) If wall strength is too small, welding is not advisable

Table 9.2 Standard values for socket welding of PE pipes and fittings under atmospheric temperature of 20°C and moderate measurable air current (DVS 2207 Section 1)

Execution

For heating, the pipes to be welded are to be shoved on the heating element of the device up to the mark designating the welding zone and fixed in place. The heating period specified in the data of table 9.2 then begins. During heating, the cross section of the pipe is to be absolutely prevented from resting on the end of the heating socket.
After completion of the heating period, the parts to be welded are to be quickly removed from the heating device and immediately pushed together without contortion up to the stopping point at the mark. In manual welding, the joining parts must be held in place for a period specified in table 9.2. The joint may only be exposed to mechanical loads after the cooling period has ended. The heating spigot and heating socket are to be cleaned after every welding procedure using non-fraying paper and an appropriate cleaning agent (e.g. industrial alcohol).

9.2.2 Butt-welding

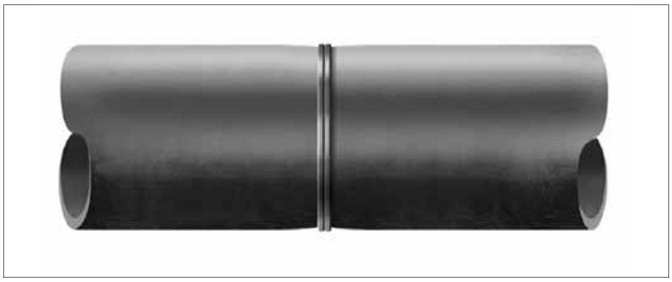


Figure 9.4

Description

Butt-welding is a very economical and reliable jointing technique in which an additional tool is required to create the non-detachable joint. Butt-welding is very well-suited to the pre-fabrication of pipe elements and the construction of special fittings.

It is a technique that is of great significance in the manufacture of welded fittings. In butt-welding, the welding surfaces (ends) of the components to be welded are first machined (planed). This produces coplanar ends that can later be simultaneously pressed against the heating element. The welding surfaces are then heated by the heating element (hot plate) and lined up under slight pressure (alignment pressure). Subsequently, heating proceeds under reduced pressure (heating time) and, after removing the heating element (conversion), the joint is formed under welding pressure. Diagram 9.1 provides a schematic representation of the butt-welding process. Adjustable heating temperatures can be varied to match wall thickness (figure 9.5).

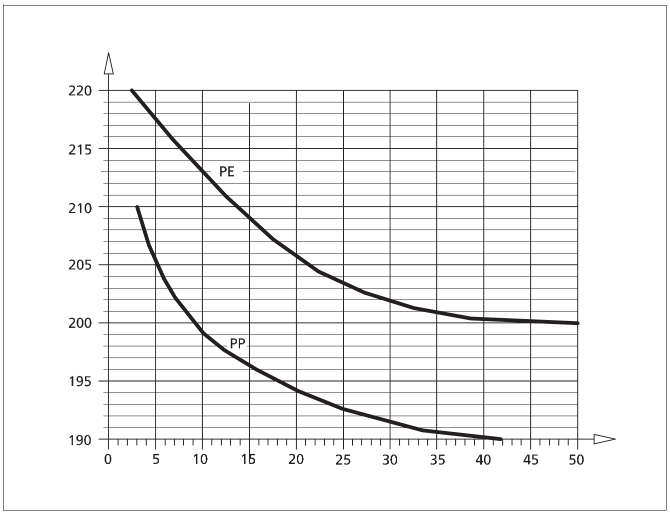


Figure 9.5 Heating temperature as s function of PE pipe wall thickness

Butt-welding process

The execution of the butt-welding process is described in 'NEN 7200 *Plastic piping for transporting gas, drinking water and waste water - Butt-welding pipes and fittings*'. ISO/TC138 has also composed working document 'ISO/WD21307' to standardise the butt-welding process.

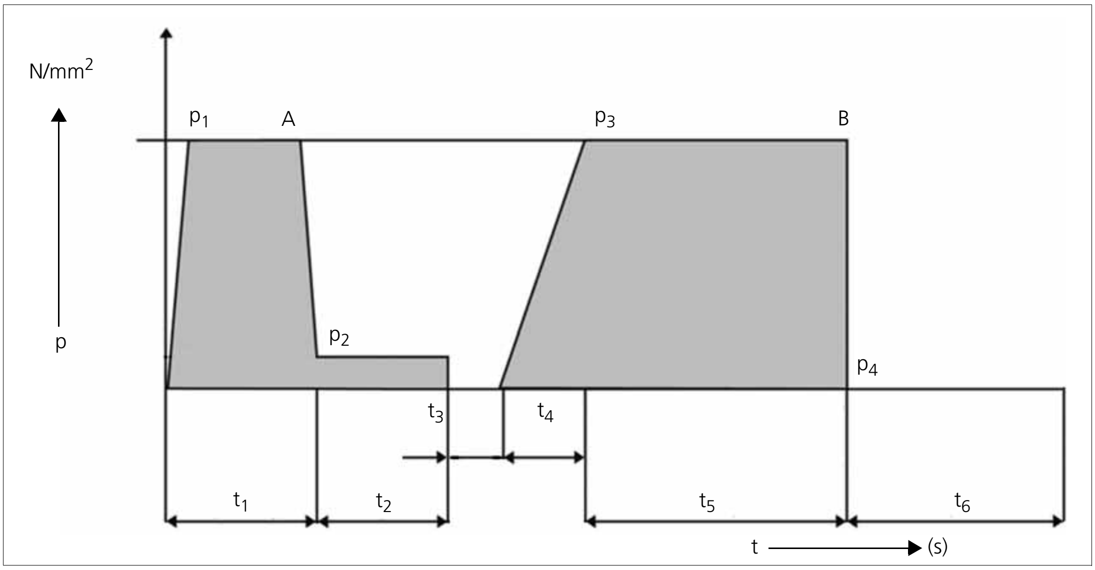


Diagram 9.1 The development of the proces of butt-welding

Sign	Name	Entity	
d_e	nominal outside diameter of pipe	mm	
e	minimum pipe wall thickness	mm	
A	bead size (end of alignment time)	mm	about (0.5 + 0.1 e) around even
B	bead size (end of cooling time under pressure)	mm	minimum 3 + 0.5 e maximum 5 + 0.75 e
p_1	pre-heating pressure	N/mm^2	0.18 +/- 0.01
p_2	heating pressure	N/mm^2	almost pressureless up to about 0.01
p_3	welding pressure	N/mm^2	0.18 +/- 0.01
p_4	cooling pressure	N/mm^2	0 (pressureless, without flexural and/or tensile stress)
t_1	pre-heating time	s	until bead size A is reached
t_2	heating time	s	(12 +/- 1) e
t_3	maximum conversion time	s	3 + 0.01 d_e
t_4	maximum built-up time	s	3 + 0.03 d_e
t_5	maximum welding time, under welding pressure	min	3 + e
t_6	maximum cooling time, under cooling pressure	min	1.5 e

Clarification of process parameters

	pipe SDR 11											pipe SDR 17										
d_e mm	$e_{(SDR11)}$ mm	F_1/F_3 * kN	A mm	F_d ** kN	t_2 s	t_3 s	t_4 s	t_5 min	B_{min} mm	B_{max} mm	t_6 min	$e_{(SDR17)}$ mm	F_1/F_3 * kN	A mm	F_d ** kN	t_2 s	t_3 s	t_4 s	t_5 min	B_{min} mm	B_{max} mm	t_6 min
32	2.9	0.05	0.8	0.003	35	3	4	6	4	7	4	1.9	0.03	0.7	0.00	23	3	4	5	4	6	3
40	3.7	0.08	0,9	0.004	44	3	4	7	5	8	6	2.4	0.05	0.7	0,00	29	3	4	5	4	7	4
50	4.6	0.12	1.0	0.01	55	4	5	8	5	8	7	3.0	0.08	0.8	0.00	36	4	5	6	5	7	5
63	5.8	0.19	1.1	0.01	70	4	5	9	6	9	9	3.8	0.13	0.9	0.01	46	4	5	7	5	8	6
75	6.8	0.26	1.2	0.01	82	4	5	10	6	10	10	4.5	0.18	1.0	0.01	54	4	5	8	5	8	7
90	8.2	0.38	1.3	0.02	98	4	6	11	7	11	12	5.4	0.26	1.0	0.01	65	4	6	8	6	9	8
110	10.0	0.57	1.5	0.03	120	4	6	13	8	13	15	6.6	0.39	1.2	0.02	79	4	6	10	6	10	10
125	11.4	0.73	1.6	0.04	137	4	7	14	9	14	17	7.4	0.49	1.2	0.03	89	4	7	10	7	11	11
140	12.7	0.91	1.8	0.05	152	4	7	16	9	15	19	8.3	0.62	1.3	0.03	100	4	7	11	7	11	12
160	14.6	1.20	2.0	0.07	175	5	8	18	10	16	22	9.5	0.81	1.5	0.04	114	5	8	13	8	12	14
180	16.4	1.52	2.1	0.08	197	5	8	19	11	17	25	10.7	1.02	1.6	0.06	128	5	8	14	8	13	16
200	18.2	1.87	2.3	0.10	218	5	9	21	12	19	27	11.9	1.27	1.7	0.07	143	5	9	15	9	14	18
225	20.5	2.37	2.6	0.13	246	5	10	24	13	20	31	13.4	1.60	1.8	0.09	161	5	10	16	10	15	20
250	22.7	2.92	2.8	0.16	272	6	11	26	14	22	34	14.8	1.97	2.0	0.11	178	6	11	18	10	16	22
280	25.4	3.66	3.0	0.20	305	6	11	28	16	24	38	16.6	2.47	2.2	0.14	199	6	11	20	11	17	25
315	28.6	4.63	3.4	0.26	343	6	12	32	17	26	43	18.7	3.13	2.4	0.17	224	6	12	22	12	19	28
355	32.2	5.88	3.7	0.33	386	7	14	35	19	29	48	21.1	3.98	2.6	0.22	253	7	14	24	14	21	32
400	36.3	7.47	4.1	0.41	436	7	15	39	21	32	54	23.7	5.04	2.9	0.28	284	7	15	27	15	23	36
450	40.9	9.46	4.6	0.53	491	8	17	44	23	36	61	26.7	6.39	3.2	0.36	320	8	17	30	16	25	40
500	45.4	11.67	5.0	0.65	545	8	18	48	26	39	68	29.7	7.90	3.5	0.44	356	8	18	33	18	27	45
560	50.6	14.58	5.6	0.81	607	9	20	54	28	43	76	33.2	9.89	3.8	0.55	398	9	20	36	20	30	50
630	57.2	18.53	6.2	1.03	686	9	22	60	32	48	86	37.4	12.53	4.2	0.70	449	9	22	40	22	33	56

* *at specific welding pressure of 0.18 N/mm^2*

** *at specific welding pressure of 0.1 N/mm^2*

Table 9.3 Process parameters for butt-welding

Welding polyolefins

Butt-welding of PE pressure pipes involves the following steps:

Preparation

The following rules are important for the execution of a good butt-weld:

- The worksite must be a sheltered location arranged so that it is independent of weather conditions.
- The functionality of the butt-welding equipment must be regularly checked. This especially applies to any machine used on a construction site.
- The pipes and/or fittings to be welded must be pressed against the machine in a line so that no discernible misalignment of the walls exists. Wall misalignment may be no more than 10% of wall thickness.
- The pipe and/or fitting surfaces to be welded must be planed to make them coplanar and parallel to the hot plate. The surfaces can consequently be evenly heated, and planing also removes the oxidation layer on PE. Failure to remove this layer will prevent a good butt-weld from forming.
- The prepared surfaces must be kept clean: welding surfaces must be free of oil, grease and dust.
- The hot plate must be regularly cleaned with a non-fraying paper and an appropriate cleaning agent (see manufacturer information).
- The temperature of the hot plate must be between 200°C and 220°C. The higher temperature is to be used with smaller wall thicknesses. The maximum temperature deviations are shown in table 9.4.

Hot plate with electrical temperature control

Usable surface	$\Delta\vartheta_1$	$\Delta\vartheta_2$	$\Delta\vartheta_{tot}$
up to 250 cm^2	5°C	3°C	8°C
> 250 cm^2	7°C	3°C	10°C

Table 9.4 Max. temperature deviations

$\Delta\vartheta_1$ = max. temperature difference within usable surface
$\Delta\vartheta_2$ = temperature difference over control interval
$\Delta\vartheta_{tot}$ = $\Delta\vartheta_1 + \Delta\vartheta_2$ = max. acceptable temperature deviation from setting

Preparing the welding surfaces

Surfaces are planed until they are coplanar and parallel to the hot plate (see figure 9.6).

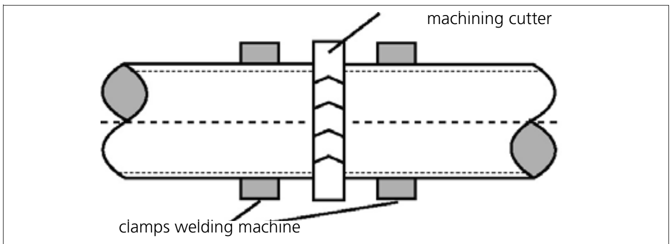


Figure 9.6 Planing welding surfaces

Heating

Both welding surfaces are pressed against the hot plate under the force of a heating pressure. Better preparation causes a more even weld bead to form. The pipe and/or fitting are held against the hot plate until the welding bead has reached a certain height. The heat saturation phase then follows.

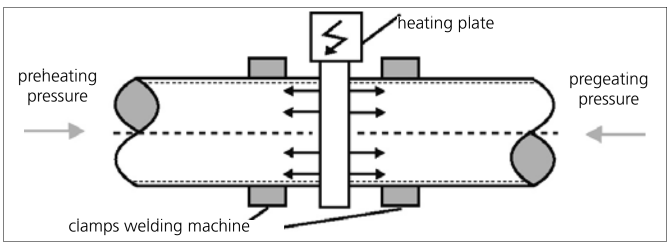


Figure 9.7 Heating a pipe or fitting

Heat saturation

During heat saturation, the welding surfaces must be held against the hot plate under slight pressure (just 0.01 N/mm^2). Heat will then be spread evenly through the pipe, and the weld bead will increase in height.

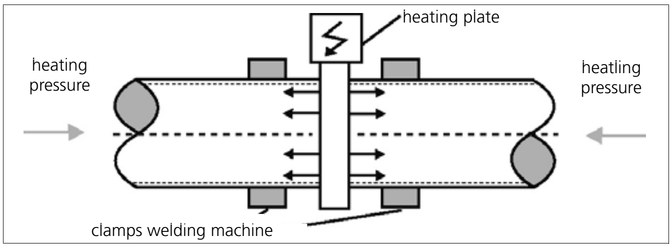


Figure 9.8 Heat saturating a pipe or fitting

Conversion

Between heating/heat saturation and welding, the hot plate must be removed and the welding surfaces pushed against each other. To avoid cooling, the removal of the hot plate must occur quickly.

Welding and cooling

The surfaces to be welded must be abutted very shortly after the heating time. The welding pressure is then to be applied during the pressure build-up time. According to NEN 7200, the specific welding pressure for PE100 is P = 0.18 N/mm^2.
The build-up of welding pressure must occur evenly with a deviation of no more than 0.01 N/mm^2.
A too rapid build-up of pressure will cause the plastic material to be pushed aside, pushing the surfaces too slowly together will cause the material too cool down too fast. Weld quality is insufficient in both cases.

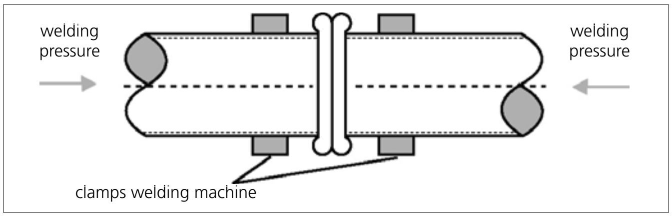


Figure 9.9 Welding / cooling a pipe or fitting

Cooling

The welding pressure is maintained throughout the entire cooling time. It must also be ensured that no mechanical load is placed on the welding seam. The welding zone is to be prevented from cooling to quickly or abruptly. After welding, an even double bead must have been formed. The form of the bead will give an initial indication about the evenness of the welding seam. Varied bead composition or irregular bead formation may not be an indication of poor workmanship. Often, it is the different flow behaviours (viscosities) of the molten plastics from the two components being welded that are responsible. The bead size "K" must always be > 0.

Diagram 9.1 and table 9.3 show the standard values for the weldcycle. The settings for the welding machine depend on machine resistance. The welding tables for the machine must be used to set welding pressure.

9.2.3 Electrofusion

Description
The electrofusion coupling underlying the process is employed to connect pipe components in pressure pipe installations for gas and water supply networks, industrial facilities and pressurised drainage systems. The process is suitable for connecting pipe components of the series:

ISO-S pipe series number / SDR
- S 5 / SDR 11 (PE100)
- S 8 / SDR 17 (PE100)

Figure 9.10 Electrofusion coupling

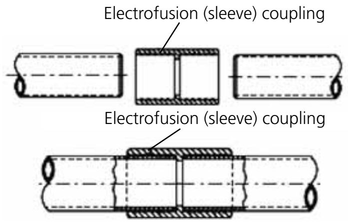


Figure 9.11 Electrofusion

Like butt-welding, electrofusion is a widespread welding technique in PE pipe construction.
Applications have the following advantages:
- simple procedure throughout the entire welding process
- uncomplicated operation of the welding apparatus
- regular quality of the welded joint due to reproducible equipment settings
- longitudinally rigid joint
- mo excess or weld bead inside pipe
- welding made possible for hard to access locations

Welding occurs in an overlapping form which means that the pipes and/or fittings are joined to each other through an electrofusion coupling. The resistance coil (heating coil) integrated into the electrofusion coupling are heated by an electrical welding unit, causing the surfaces of the pipes and the coupling (in immediate contact with the heating coil) to be plasticised. The thermal expansion of the plastic creates welding pressure so that the effects of these two parameters result in a homogeneous connection between coupling and pipe or fitting at the end of the welding time. The VM 102 guideline for welding practice applies to electrofusion on pressure pipe installations. The guideline also makes recommendations about quality assurance and describes possible testing methods.

Electrofusion process
The execution of the electrofusion process is described in the welding recommendation 'Electrofusion sleeve welding of thermoplastics'.

Preparation
- Inspect pipe and fitting for damage and proper sizing
- Check state and function of welding unit
- Take protective measures if weather conditions make it necessary
- Pipes, fittings and welding equipment are to be kept at a constant ambient temperature between -10°C and + 45°C
- Do not weld when medium is being discharged

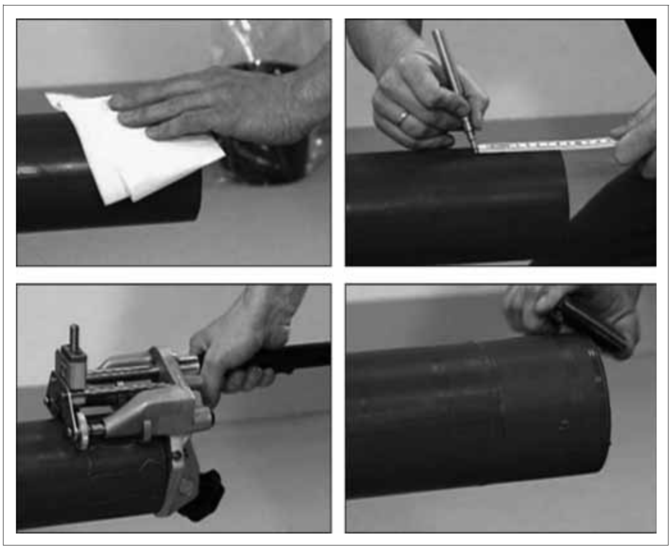


Figure 9.12 to 9.15

Pretreatment
1. Cut the pipe square
   - slanting cuts can result in inadequate melting, overheating or burning
2. Clean the pipe
3. Mark the welding zone
4. Remove oxidation layer
   - scrape off a long even continuous chip (min 0.15 mm thick)
   - an excessively thick chip will prevent the gap between coupling and pipe from being filled
   - scraping 5 mm extra in width is a sign of good workmanship
   - filing or sanding is not permitted
5. Debur the pipe
6. Make oval pipe round, be careful with pipes on cylinders and drums
   - use rounding clamps if ovality >1.5% diam. or >1.5 mm

Figure 9.16 to 9.18

Cleaning
1. Mark the welding zone again
2. Clean the welding surface of the pipe
   - welding surfaces must be absolutely clean
   - use PE cleaning agent and absorbent, non-fraying uncoloured paper
3. Clean inside of coupling
   - take fitting out of packaging just before use
   - prevent rubbing contaminants from untreated surfaces from entering the welding zone

Welding polyolefins

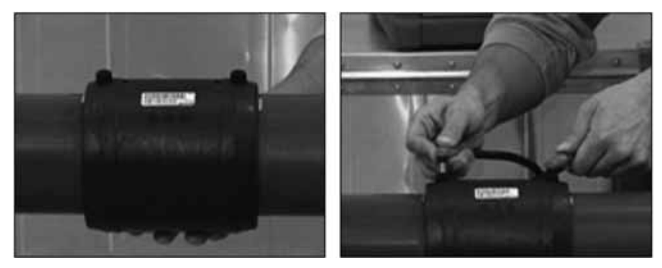


Figure 9.19 and 9.20

Positioning

1. Push the pipe into the fitting up to the mark
2. Connect contact plugs to fitting: pay attention to tension free assembly
    - shove pipe straight into coupling
    - do not rotate
    - coupling should be movable by hand
3. Guideline VM 102 prescribes: use clamps for tension-free assembly

Figure 9.21

Welding

1. Scan barcode with hand reader
2. Start welding process: electrofusion unit automatically regulates the amount of energy and welding time
    - safe distance to welding location is 1 m
3. Compare actual with required welding time
4. Note actual welding time on the pipe
    - welding indicator provides an impression of the completed weld, correctness is also indicated by the welding unit

Figure 9.22 to 9.25

Cooling

1. Adhere to the cooling time (CT) on the barcode before moving the connection
2. Cooling time prior to testing or operation pressure is indicated in the tables of the FRIALEN assembly manual

Figure 9.26

9.2.4 Hot gas welding

Description

- Type of welding

Hot gas welding is divided into:

- hand welding
- speed welding
- extrusion welding

The fundamentals for individual extrusion welding techniques are provided in the guidelines of DVS 2207 Sections 2, 4 and 5. The application of hot gas welding requires special knowledge and skills from the welder. The requirements are contained in DVS 2212 Section 1.

- Functional principles

In hot gas welding, the welding surface and filler are turned into a plastic state by hot air and welded to each other under pressure.
The heating of the air occurs in the welding tool. It must be absolutely certain that the hot air is free of moisture, dust and oil. Hot gas welding techniques will be described in more detail below.

1. Hand welding

In hot gas hand welding, the hot air is usually supplied to the elements to be welded through a round nozzle. The filler material must be appropriate for the welding substrate. Mostly, the filler material used is in the form of a rod with a diameter of 3-4 mm. For welding, the rod is placed in the seam at an angle slightly off perpendicular. With a light fanning motion, the round nozzle is pointed at the seam so that the hot air stream simultaneously heats both the rod and the substrate. By pressing down perpendicularly on the rod, the filler is pushed along the welding seam and, in this way, heated in the lower, curved area. A wave forms ahead of the welding thread and weld beads on both sides of the seam (figure 9.27).

1 Welding rod
2 Force
3 Hot air
4 Round nozzle
5 Welding tool
6 Fanning motion
7 Welding direction
8 Wave
9 Weld bead
10 Welding seam

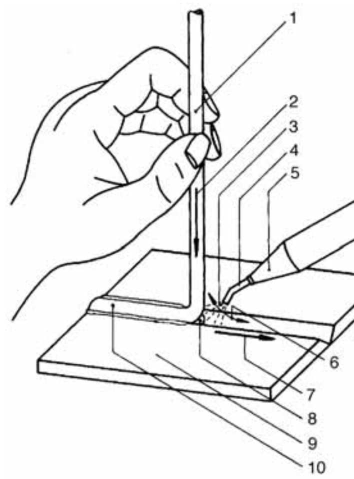


Figure 9.27 Hot gas hand welding

2. Speed welding

In hot gas speed welding, the welding rod is fed through a speed-welding nozzle, heated by the hot air and pressed into the weld joint by a beaked-form tip at the bottom of the nozzle (figure 9.28).
The forward movement of the nozzle is, as a rule, strong enough to draw the welding rod through the nozzle. The welding speed of speed welding is 3-4 times faster than that of hand welding. In contrast to hand welding, this welding procedure can evenly apply the required welding pressure. Speed welding cannot, however, be used in positions that are difficult to access.

1 Welding rod
2 Hot air
3 Welding tool
4 Welding direction
5 Weld bead
6 Welding seam
7 Force
8 Speed welding nozzle

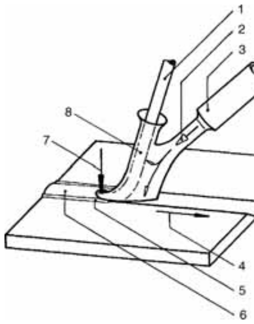


Figure 9.28 Speed welding

3. Extrusion welding

Extrusion welding is a partially mechanised hot-gas welding technique, primarily used to join thick-walled components. There are four variants of extrusion welding that are used. The data about hot-gas extrusion welding can be found in the guidelines contained in DVS 2207 Sections 4 and 5, as well as in DVS 2209 Sections 1 and 2.

Varieties of hot gas extrusion welding

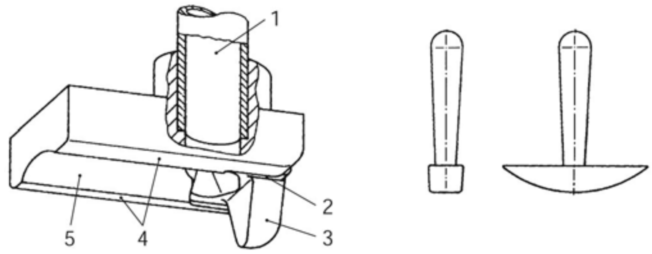
- Variant I: Discontinuous procedure with transfer of the filler to the preheated joint
- Variant II: Continuous procedure with hand tool (screw)
- Variant III: Continuous procedure with filler transfer hose between extruder and weld head
- Variant V: Continuous procedure with hand tool (plunger)

Figure 9.29 Varieties of hot gas extrusion welding

The principle machinery used in all the different variants of extrusion welding is the same.

The welding equipment consists of:
- Plasticising unit (extruder) for preparing the weld filler
- Heating using (hot gas tool) to heat the welding surfaces
- Tool to apply the required welding pressure in the form of a welding shoe or pressure tool (figure 9.30)

Welding show **Pressure mechanism**



1 Extrudate feed
2 Recess
3 Nose
4 Contact surfaces
5 Pressure mechanism / sliding surface

Figure 9.30 Welding shoe and pressure mechanism

The form of the welding tool or pressure tool depends on the procedure and weld shape. Welding shoes are most made of PTFE (Polytetrafluorethylene).
Hot air nozzles must be constructed in such a manner that the air is evenly distributed to the nozzle outlet and the temperature largely remains constant.
The commonest type is the hand extruder, which is constructed by design to have little weight and can therefore be operated by hand with relative ease. The extruder is made in both semi-automatic and fully automatic models. Extrusion welding enable various weld shapes to be made (e.g. V seam, double V seam, fillet weld). In a continuous process, the extruder deposits molten material (extrudate) in the weld joint, which is heated by the hot gas. The extrudate is placed in the joint by means of the weld shoe and pressed with the required welding force, causing a homogeneous weld to be made with the substrate surface, which has been plasticised by the hot gas.
Very large joints require extrudate to be applied in several runs. Welding with the extruder requires trained and experienced professionals, as the proper advancing speed together with the necessary pressure have a large influence on the quality of the weld. Table 9.6 shows the welding parameters (standard values) for the individual hot-gas extrusion variants.

Material Short symbol	Type of welding	Welding force (N) Round Ø 3 mm	Welding rod Round Ø 4 mm	Hot air temperature (°C)	Air quantity (l/min)
PE	Hand welding	6-10	15-20	300-350	40-60
PE	Speed welding	10-16	25-35	300-350	40-60

Table 9.5 Welding parameters: standard values for hand and speed welding

Method	Variant	Material thickness (for single-run welding) (mm)	Temperature of molten mass (°C)	Temperature of hot air (°C)	Air flow rate (l/min)	Weld filler flow rate (kg/h)
continuous	Variant II	0...15	200...230	250...300	≥ 300	0...2
procedure	Variant III	0...15	200...230	250...250	≥ 300	0...4
		15...30	200...230	250...300	≥ 400	0...6
	Variant V	0...15				
discontinuous procedure	Variant I	0... 5	200...230	250...300	≥ 300	0...4

Table 9.6 Welding parameters for hot-gas extrusion welding

Notes to table 9.6:

1 If thicker components have to be welded, several welding runs are made.
2 The temperature of the molten mass is measured with a probe thermometer in the extrudate feed.
3 The hot-air temperature is measure between the nozzle outlet and 5 mm in the nozzle.
4 Air flow means here cold air at 20°C and one atmosphere in operation-ready state. In the case of air supply from compressed air networks, air pressure can be measured behind the air flow rate metre and by considering pressure and air flow conversion. No oil or grease may be included in the air.

- Areas of application

The described extrusion welding techniques are predominantly used in:

- Machine construction (shaft and tank manufacture).
- Pipe construction (welding of casing pipes). The use to weld casing pipes is, however, rather infrequent.

Extrusion weld process - Preparation

To ensure weld quality, the preparation, as in all of the above welding procedures, must be carefully done.

In preparing the weld, the following list of points should therefore be attended to:

- The welding surfaces and the adjacent border zones must be mechanically prepared before welding. There are mechanical pre-process tools that are suitable for this purpose, such as scrapers and graters. Parts affected by atmospheric and chemical influences must be treated prior to welding right back to the unaffected zone.
- Care therefore needs to be taken that, during a welding process performed in the open, no weather conditions (e.g. wind, rain) may affect effectiveness. When ambient temperatures are under +5°C, the welding site must be protected (e.g. by a heated tent). The temperature variation in the immediate vicinity should be no more than 10°C throughout the duration of the welding process.
- The welding zone must be dust, oil and grease free.
- The functionality of machines and equipment are to be tested prior to welding. At such time, the appropriate welding parameters are to be set and the standard values to be verified against the actual values. The results are to be documented in a test record.

- Weld shapes

The shapes of the weld correspond to the conventional and well-known forms used in metalwork (e.g. filet weld, V seam, double V seam). Welding forms are described in the technical bulletins DVS 2205 Sections 3 and 5. Standard values for the welding parameters are listed in the technical bulletin DVS 2205 Section 3. Except from DVS 2207 Section 3 on the welding seam structure in hot gas welding.

	Material thickness (mm)	Welding rod x diameter
V seam	2	1x4
	3	3x3
	4	1x3+2x4
	5	6x3
Double V seam	4	2 (1x4)
	5	2 (3x3)
	6	2 (3x3)
	8	2 (1x3+2x4)
	10	2 (6x3)

Table 9.7 Weld shape as a function of material thickness with a cone angle of 60°C

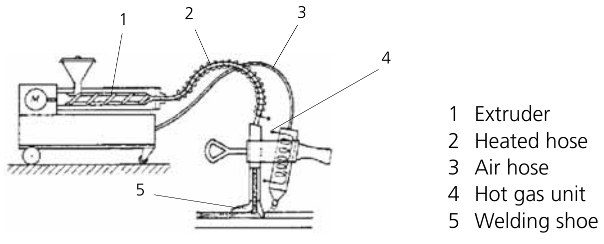


Figure 9.31 Extrusion welding (Variant III)

9.3 Test procedures for evaluating welds

Completed components are, as a rule, only tested by non-destructive test procedures. Destructive test methods are employed in cases involving damage claims or in the development of new materials and manufacturing procedures.

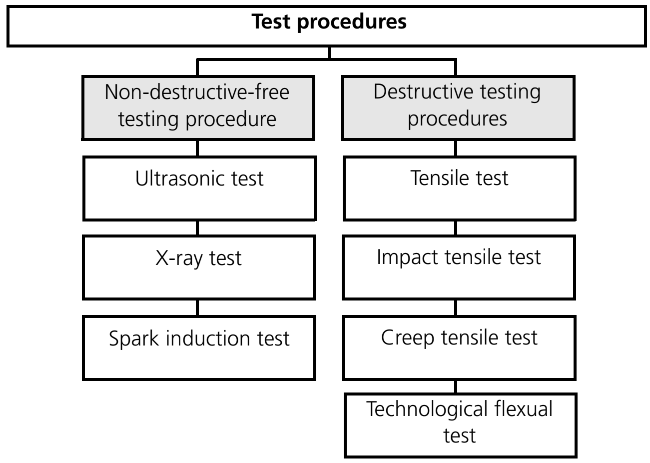


Figure 9.32 Test procedures used for plastic

The most frequently used test in plastic pipe construction is the visual inspection. This involves a purely external visual evaluation of semi-manufactured products, components and welds.

The visual inspection of butt-welds can be performed without special tools if the tester has the appropriate knowledge and experience.

The possibility of visual evaluation of electrofusions is limited. The checks therefore concentrate more on weld preparation and the implemented welding parameters.

The evaluation of welded joints for in pressure systems most used weld techniques is described in NEN 7200 and VM 102.

9.3.1 Visual inspection of butt-welds

Butt-welds are primarily visually inspected. The evaluation of butt-welds is described in NEN 7200.

The bead must be of uniform shape. The welding area must be free of tears, contamination or other damages. The dimensions of the bead must mach table 9.3.

The bead form is an indication of careful performance of the welding process. Both beads must be of the same form and size.

Differences between the beads can be caused by differences in the flow behaviour of the welding surfaces joined together. The weld can still be functionally sound. Figure 9.33 shows a good weld with identical beads.

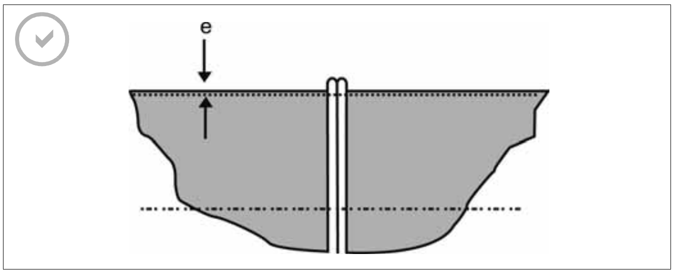


Figure 9.33 Butt-weld with identical welding beads (good)

Misalignment of the two ends can have various causes. Uneven narrowing of one of the ends or ovality are two of the possibilities. As long as the difference is smaller that 10% of the pipe / fitting wall thickness, the weld can be regarded as "acceptable" (see figure 9.34).

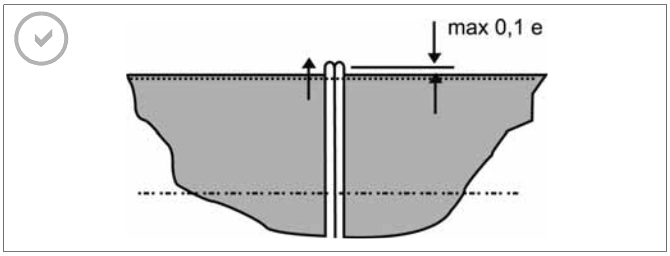


Figure 9.34 Butt-welding with acceptable wall misalignment

Too high heat or too strong pressure causes the beads to be too large. Figure 9.35 shows that the uniformity of the two beads makes this weld still "acceptable".

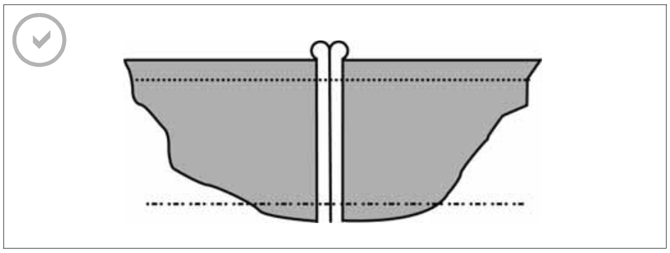


Figure 9.35 Butt-weld with welding beads that are too large but still acceptable.

Figure 9.36 represents a weld with beads that are too small, suggesting that the heating was too low and/or pressure too weak. In thick walled pipes, undersized beads are often associated with the formation of shrinkage cavities. These sorts of welds must be deemed "unacceptable".

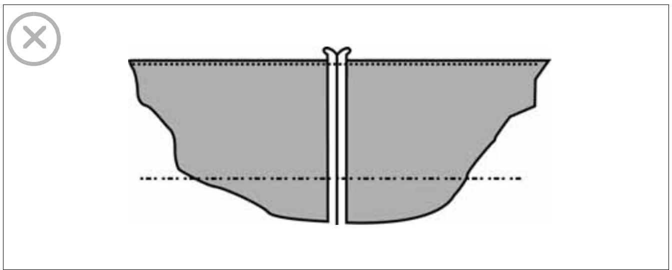


Figure 9.36 Unacceptable butt-weld

Figure 9.37 provides a cross-sectional view of a good weld. The bead is round, notch-free and with a misalignment of max. 0.1 e. Bead size "K" must be at least equal to wall thickness e.

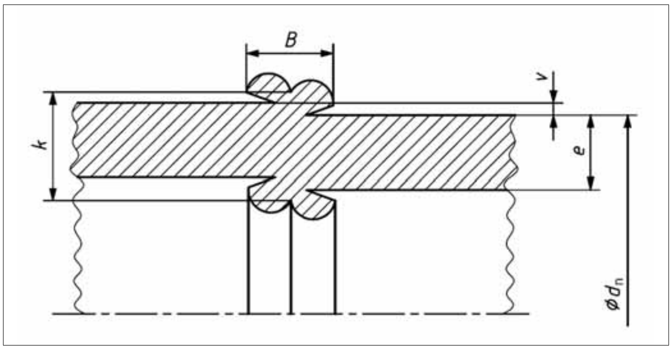


Figure 9.37 Cross-section of a good weld

9.3.2 Visual inspection of electrofusion joints

An indication of weld quality based on the bead form in butt-welding cannot be similarly obtained in electrofusion. Any opportunity to test the plasticisation and associated weld between electrofusion sleeve and the corresponding components to be welded can only occur on the basis of the changed indicators found on the coupling. If they do not provide any clear view of the quality of the weld and if the joint is not to be destroyed, one of the non-destructive testing procedures must be employed (e.g. ultrasound, X-rays). These are generally expensive and to inaccurate for evaluating the weld quality. In visually inspecting the weld, it must be absolutely certain that there are no discernible visible traces (e.g. scratches, tarnished surfaces, scoring in the immediate area of the coupling) relating to the mechanical procedures required for faultless weld quality.

The following description about evaluating electrofusions is a copy from NIL weld practice guideline VM102:

An electrofusion weld is of good quality when the weld has sufficient mechanical strength over the long term, and the welding zone is homogeneous and free of cracks, contaminants and holes. In addition, verification must be made of the correct welding and cooling times used in the process. For proper quality control, it is also necessary to make a few trial welds prior to the production welding. These are performed under controlled worksite conditions using the applicable type of material and accurately observing the welding conditions (welding and cooling times). A few of these welds are to be subjected to destructive analysis:

- on the basis of a tensile test
- on the basis of a detachment test

The test welds can be further used as reference material for visual inspections of the actual welds.

All joints welded with deviant parameters or in which the welding does not meet stated requirements concerning their execution are to be removed.

Welding polyolefins

Visual inspection
Apart from the sample destructive testing, an accurate visual inspection is of crucial importance, together with the establishment of welding parameters. The appearance of the actual welds must be scrupulously examined and compared to the reference welds. No large deviations from the reference welds may occur.

No scratches, impurities or other damage may appear in the welding zone.

Attention also has to be paid to:
- proper insertion depth of the pipe in the fitting.
- alignment of the various components in the pipe system.
- deviation from the straight position of the pipe in the coupling. No more that 1 mm deviation may be measured over a distance of 300 mm from the socket (angle of deviation < 0.2°).
- resistance coil is imperceptible.
- regular filling of the original gap between coupling and pipe.
- heat damage.
- bonding flaws due to bent pipes or insufficient shape-retention of saddles.
- the ovality of the pipe in the coupling. After welding, this may not be more that 1.5% of the average outside diameter of the pipe, with a maximum of 1.5 mm.
- the presence of welding indicators, if any.

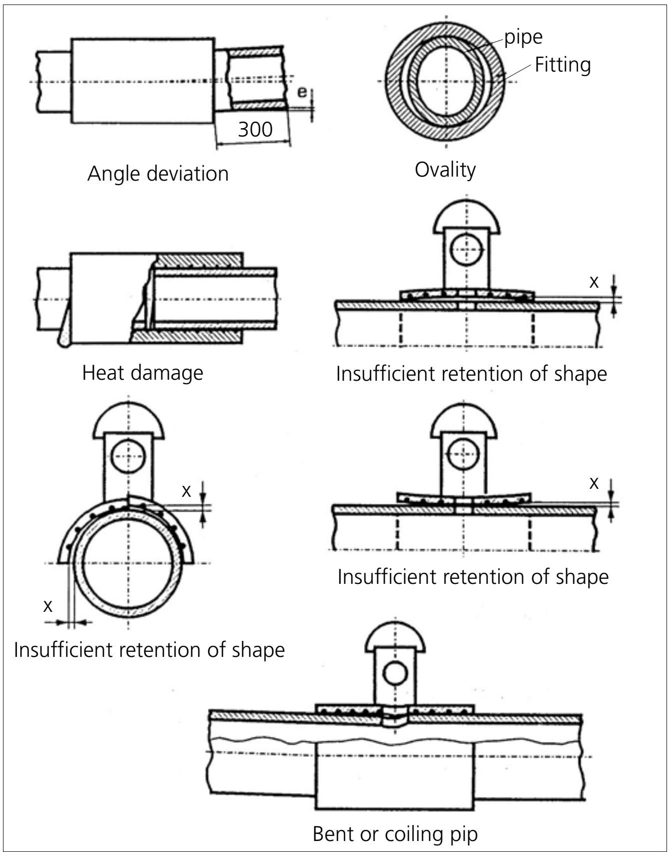


Figure 9.38

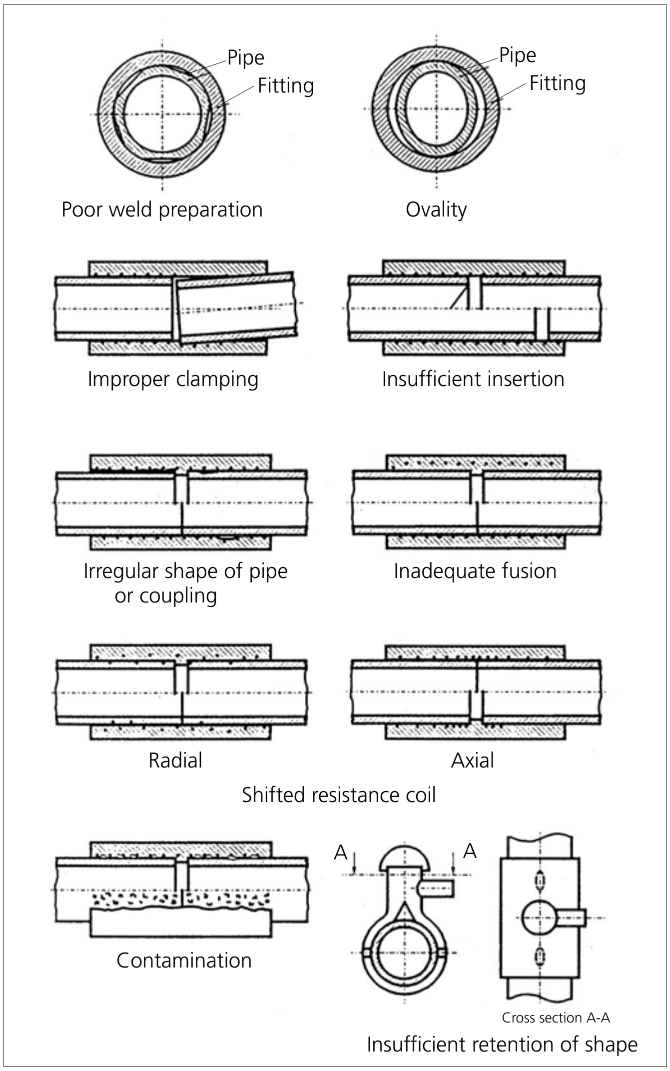


Figure 9.39

9.3.3 Testing joints produced by hot gas welding
Ultrasonic and spark induction tests are two non-destructive testing procedures that have proven use for machine construction in which hot gas extrusion welding is predominantly used. However, a simple visual inspection of the weld is often helpful in many cases. Relatively accurate recognition and location of flaws inside of a welded joint requires testing by means of ultrasound. These days, there are appropriately constructed senders and receivers for individual weld forms with which an experienced ultrasonic tester can recognise and properly interpret the smallest defect in the weld. Well-trained personnel having appropriate experience with this test method are, however, an absolute necessity, which makes the costs of such a test significantly high. In contrast, the spark induction test is substantially less expensive and simple to perform.

9.4 Chapter summary

PE welding	Welding is for plastic pipe systems and equipment construction a common jointing technique. PE pipe systems are prominently jointed by butt-welding and electrofusion methode.
Butt-welding equipment	The principle pieces of butt-welding equipment are: plane (in pipe construction machines), hot plate, clamping tool and hydraulic unit. Construction site (portable, e.g. trench welding machines) and workshop machinery (stationary welding machines) may be used. Construction-site machines are increasingly being converted to CNC controlled machines (fully automatic), which enable the construction-site operation to ensure reproducibility of welding joints and the automatic production of reports.
Bead formation in butt-welding	Visual inspection of the form in which the bead is created can provide an indication of weld quality. However, such evaluation requires sound, appropriate, practical and theoretical expertise about the welding process.
Electrofusion	Electrofusion is a practice also known as electric "sleeve" or "saddle" welding. The joining of the welding mates is effected by an electrofusion coupling on the inside of which an integrated heating coil (electrical resistance coil) is charged with current during the welding process and is heated as a result of its electrical resistance. As a consequence, the surfaces of both the coupling and the pipe or fitting (i.e. the contact areas) are plastcised. The process creates a homogeneous joint between electrofusion coupling and pipe/fitting.
Hot gas welding techniques	Hot gas welding is distinguished into hand welding, speed welding and extrusion welding. The plasticisation of the welding zones occurs by heating the welding surfaces (and filler material) with hot air. For this purpose, hot air is forced through a nozzle shaped specifically to sufficiently heat and plasticise the joint surfaces.
Hand welding	The welding tool in which the appropriate nozzle is mounted (in most cases a round nozzle) is moved in a fanning motion over the surfaces to be welded. In this way, the substrate and welding filler are heated until the material in the welding zone is placticised. The filler (mostly in the form of a rod) is perpendicularly pressed by hand into the welding zone. The necessary welding or joining pressure is applied by pushing down the welding rod by hand during the welding process. Appropriate welder skills and abilities are therefore required.
Speed welding	The heating of the substrate and filler occurs by means of the beak-shaped tip at the lower end of the speed-welding nozzle. The necessary welding pressure is applied by this nozzle.
Extrusion welding	Four different variants of extrusion welding are used. The individual variants are different in terms of material supply, type of welding equipment (e.g. hand extruder) and pressure tool (e.g. plunger, welding shoe). An extrusion welding extruder generally has the following elements: plasticising unit, hot gas tool and device for applying the required welding pressure.
Welding shoe / pressure tool	A welding shoe or pressure tool has an effect on the appearance, formal possibilities and quality of the weld. This equipment is manufactured and adjusted in accordance with the desired seam width and form. The welding shoe has the function of evenly distributing the molten material produced in extrusion into the joint and applying the appropriate welding pressure.
Tools used in extrusion welding	Work performed in extrusion welding makes use of a hand or stationary extruder with swivel head and transfer hose.
Weld preparation	Weld preparation is extremely important in all welding procedures. It has a significant effect on the quality of the weld and should therefore be undertaken with utmost care.
Testing welds	A distinction is made between destructive and non-destructive tests. Destructive test methods are chiefly used to evaluate cases involving damage claims.
Evaluating welded joints	Visual inspection is a non-destructive method of evaluating welds frequently employed in practice. This evaluation is primarily concerned with appearance (e.g. welding bead of butt-welding). It is however a type of assessment requiring theoretical and practical knowledge, as well as appropriate tester experience. If more accurate indications of weld quality are needed, then a more expensive non-destructive (e.g. ultrasonic or X-ray test) or destructive testing method has to be adopted.