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Plastics pipes and fittings — Butt fusion jointing procedures for polyethylene (PE) piping systems

Tubes et raccords en matières plastiques — Modes opératoires d'assemblage par soudage bout à bout de tubes et raccords en polyéthylène (PE)

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 4, *Plastics pipes and fittings for the supply of gaseous fuels*.

This third edition cancels and replaces the second edition (ISO 21307:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— Added calculation of gauge pressure in 4.7;

— Included normative non-destructive joint integrity testing (visual examination with requirements) in 6.3;

— Updated process parameters in Tables 1, 2, A.1, B.1 and C.1.

Introduction

With the increasing use of polyethylene (PE) pipes of larger diameters and wall thicknesses there is a need for this document which provides details on three butt fusion procedures. This document is developed for the benefit of countries without a national standard or technical specification for butt fusion procedures of PE pipes. High quality butt fusion welds can be obtained with all three butt fusion procedures mentioned in this document. The choice for one of these three procedures can depend on experience, on the practical trials of the three butt fusion procedures and on availability of equipment.

Plastics pipes and fittings — Butt fusion jointing procedures for polyethylene (PE) piping systems

1 Scope

This document establishes general principles regarding the procedure used in the construction and quality assessment of butt fusion jointing of polyethylene (PE) piping system components specified in accordance with relevant ISO standards. These components are installed in accordance with the relevant codes of practice, national regulations or industry guidance. Specifically, this document specifies three butt fusion jointing procedures for PE pipes and fittings. These are:

— single low-pressure fusion jointing procedure;

— dual low-pressure fusion jointing procedure;

— single high-pressure fusion jointing procedure.

This document takes into consideration the materials and components used, the fusion jointing procedure and equipment and the quality assessment of the completed joint. It can be applied in conjunction with appropriate national regulations and standards.

NOTE 1 The references for these procedures are given in the Bibliography.[1][2][3][4][5][6] Single low-pressure fusion jointing procedure is derived from multiple procedures and agreed by experts, given in the Bibliography [1][2].

NOTE 2 The three procedures detailed in this document are based on those most commonly used. It is not the intention that one or more of these procedures be used to replace well established and verified industry based procedures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12176-1, *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 1: Butt fusion*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
heater plate temperature
measured temperature on the surface of the heater plate where the pipe or fitting wall cross-section makes contact

3.2
nominal wall thickness
e_n
wall thickness tabulated in ISO 4065[1)], corresponding to the minimum wall thickness $e_{y,min}$ at any point e_y

3.3
nominal outside diameter
d_n
numerical designation of size which is common to all components in a thermoplastics piping system other than flanges and components designated by thread size

3.4
standard dimension ratio
SDR
numerical designation of a pipe series, which is a convenient round number, approximately equal to the dimension ratio of the nominal outside diameter, d_n, and the nominal wall thickness, e_n

3.5
drag pressure
gauge pressure required to overcome, on a given machine, the sliding frictional drag force of the machine and pipe

Note 1 to entry: Drag pressure, if present, can be a positive or negative value.

3.6
bead-up
initial melt under pressure around the circumference of the ends of the pipes or fittings which ensures that complete pipe or fitting to heater plate contact is achieved

3.7
bead-up pressure
pressure exerted on the heater plate by the pipe or fitting ends during the bead-up phase of the jointing cycle

Note 1 to entry: The value of the corresponding gauge pressure is calculated with Formulae (1) and (2).

3.8
bead-up size
bead size formed on the pipe or fitting ends during the bead-up phase

3.9
heat soak
portion of the heating cycle done at 0 to drag pressure so that the heat can melt the pipe or fitting to a depth sufficient for proper mixing and fusion

3.10
heat soak pressure
pressure required to maintain the pipe or fitting in contact with the heater plate taking into account the drag pressure

3.11
0 to drag pressure
lowest possible pressure during the heat soak that will allow the pipe or fitting to remain in contact with the heater plate, up to a maximum of the current drag pressure

Note 1 to entry: The drag pressure required to move the pipe or fitting may be much higher than the pressure required to maintain pipe or fitting/heater contact during heat soak.

1) To be published.

3.12
heating cycle
part of the welding process in which pipe or fitting ends are in contact with the heater plate composed by bead up pressure and followed by heat soak pressure

3.13
heat soak time
time during which the heater plate is in contact with the pipe or fitting ends at the heat soak pressure

3.14
minimum bead size after heating
minimum value of bead size to be attained after completing the heat soak time

Note 1 to entry: Single high-pressure butt fusion procedure only.

3.15
heater plate removal time
time taken to separate the pipe or fitting ends from the heater plate, remove the heater plate and close the carriage in order to bring the molten pipe or fitting ends together

3.16
fusion jointing pressure
interfacial pressure
actual pressure exerted on the pipe or fitting ends during jointing

Note 1 to entry: The value of the corresponding gauge pressure is calculated with Formulae (1) and (2).

3.17
gauge pressure
actual pressure (bead-up pressure or fusion jointing pressure with drag pressure) in the cylinders of the butt fusion jointing machine read by the gauge

3.18
fusion jointing time
time period allotted for bead roll-over before cooling-cycle reduced pressure

Note 1 to entry: Dual low-pressure butt fusion procedure only.

3.19
cooling-cycle reduced pressure
pressure, exerted on the pipe or fitting ends during the cooling cycle of the dual low-pressure procedure after fusion jointing time

Note 1 to entry: The value of the corresponding gauge pressure is calculated with Formulae (1) and (2).

3.20
cooling time in machine under pressure
time period during which the butt fusion joint remains under pressure when still clamped in the machine

3.21
cooling time in machine without pressure or out of machine
additional cooling period that may be required after the cooling time under pressure to ensure optimum joint strength, particularly when working at high ambient temperatures and prior to rough handling or pipe installation

3.22
operator
qualified person authorized to construct polyethylene (PE) systems from pipes and/or fittings, based on a written procedure agreed by the pipeline operator according to ISO/TR 19480

3.23
pipeline operator
private or public organization authorized to design, construct and/or operate and maintain a pipeline supply system

3.24
dummy joint
unfinished joint made prior to production welding to ensure cleanliness of the heater plate in which the welding procedure is stopped after the heat soak time

3.25
jointing session
uninterrupted series of welds made with the same parameters and same equipment

3.26
rough handling
any action whereby stresses are applied to the fused joint, such as tensile and bending forces

Note 1 to entry: Some examples of rough handling are immediately after the cooling time in the machine under pressure:

— the joint is removed from the machine by single point lifting at the joint;

— several lengths of joined pipe are pulled with the freshly made fusion joint;

— the joint is immediately subjected to a severe bending stress.

4 Butt fusion jointing process

4.1 General

Polyethylene (PE) pipes and fittings for the production of butt fusion joints in accordance with this document should conform with the relevant ISO, local or national piping system standards.

PE components with fusion ends of different SDR/DR values shall not be jointed by butt fusion.

Ambient temperatures mentioned in this document shall be measured with a thermometer with an accuracy of ± 1,0 °C.

To prevent potential contamination of welds it is recommended that welding is carried out in a shelter, and the welding equipment is sited on a baseboard or ground sheet.

It is recommended to block off the PE pipe ends to prevent contamination and reduction of the temperature of the heater plate.

It is recommended, before starting the welding procedure, to check the functioning of the fusion equipment, particularly the temperature of the heating plate on both sides.

It is recommended to record the welding data in welding protocols or on data carriers.

4.2 Principle

The principle of butt fusion jointing is to heat two pipe or fitting ends for a specified time by means of a heater plate maintained at a specified temperature. Following heater plate removal the pipe ends are brought together by applying a specified pressure, and then cooled for a specified time. Butt fusion joints shall be made by qualified operators using butt fusion jointing machines that conform to ISO 12176-1. The training and level of skill of the operator shall be in accordance with the requirements of the jointing procedure. A written jointing procedure, authorized by the pipeline operator, shall be available prior to the construction of a pipeline. Any one of the three jointing procedures mentioned in this document can be used as the basis. The jointing procedure shall include specification of the

jointing method, the fusion parameters, the fusion equipment, the jointing conditions, the level of skill of the operator, and the quality control methods to be used. Guidelines for quality control are given in Clause 6.

Key elements of the jointing process shall include:

a) cleaning the pipe or fitting ends, planing unit and heater surfaces;

b) clamping the components to be joined (pipe support with drag reducing rollers may be required to ensure proper alignment);

c) planing the pipe or fitting ends;

d) aligning the pipes or fittings;

e) measuring the drag and compensating pressure accordingly;

f) melting the pipe or fitting ends;

g) jointing the pipe or fitting ends;

h) holding the pipe or fitting ends under pressure for the duration of the cooling time in the machine;

i) completing the cooling time in machine without pressure or out of machine if required.

These key elements are explained in more detail in 4.3 to 4.11.

4.3 Cleaning the pipe or fitting ends, planing unit and heater surfaces

Before placing them in the machine, clean the inside and outside of the pipe or fittings to be joined by wiping the joint area with a clean lint-free cloth, using a suitable solvent (e.g. ethanol, isopropanol) only if necessary or if specified in codes of practice or national regulations. All foreign matter shall be removed from the jointing area.

If the pipe has a protective outer layer, it shall be peeled back far enough so that the pipe can be properly clamped in the fusion machine, unless otherwise specified by the pipe manufacturer.

Cleaning the planing unit and the heater plate surfaces shall be done using a clean lint-free cloth, a clean lint-free cloth with a suitable solvent or by making dummy joints at the start of each jointing session whenever the heater plate has been allowed to cool below 180 °C and for a change of pipe size or SDR/DR prior to commencement of production welding. The number of dummy joints to be made shall be included in the written jointing procedure and/or as specified in codes of practice or national regulations.

4.4 Clamping the components

Clamp the components in the butt fusion jointing machine and adjust as necessary to achieve proper alignment. Pipe support may be needed to achieve proper alignment and reduce drag. It is recommended to support the pipe(s) to ensure the uniformity of the drag pressure.

NOTE Pipe support can be achieved by using rollers or appropriate low friction alignment blocks, etc.

It is good practice to ensure that the pipe details printed along the two pipes are aligned and placed at the top of the machine when possible.

4.5 Planing the pipe or fitting ends

Plane the pipe or fitting ends to establish clean, parallel mating surfaces that are perpendicular to the centreline of the machine guide rods.

4.6 Aligning the pipes or fittings

Remove any shavings from the pipe or fitting ends being careful not to touch the planed surfaces. If the planed surface becomes contaminated, the surface shall be replaned.

Inspect the pipe or fitting ends for incomplete planing, voids or other imperfections, and then bring them together to check for proper alignment and gap. The pipe or fitting ends shall be rounded and aligned to ensure compliance with relevant codes of practice, national regulations or industry guidelines.

4.7 Calculation of the gauge pressure

The gauge pressure can be calculated from the following formula:

$$GP = \left(IP \times \frac{A_s}{A_c} \times 10 \right) + DP \quad (1)$$

where

GP is the gauge pressure (bar);

IP is the interfacial pressure (MPa);

A_c is the total piston area, given by the manufacturer of the butt fusion jointing equipment (mm^2);

A_s is the interfacial surface area (mm^2);

DP is the drag pressure (bar).

NOTE The interfacial pressure is the amount of force per unit of pipe area required to butt fuse the pipe or fitting ends

The interfacial surface area can be calculated from the following formula:

$$A_s = \pi \times (d_n - e_n) \times e_n \quad (2)$$

where

d_n is the nominal outside diameter of the pipe (mm);

e_n is the nominal wall thickness of the pipe (mm).

4.8 Determination of the drag pressure

Determine the drag pressure after clamping and aligning. The drag pressure shall be added to the bead up and fusion jointing pressure.

4.9 Heating the pipe or fitting ends

The surface of the heater plate that comes into contact with the pipe or fitting ends shall be clean, oil-free and coated with a non-stick coating to prevent molten plastic from adhering to the heater plate surface. Refer to the specific fusion jointing procedure for the correct heater temperatures.

Install the heater plate in the butt fusion jointing machine and bring both pipe or fitting ends simultaneously into full contact with the heater plate to produce molten surfaces for fusion jointing. To ensure that full contact is made between the pipe or fitting ends and the heater plate, the initial contact shall be made under bead-up pressure. After holding the pressure until a specified bead-up size has formed all around the pipe(s) and or fitting end(s) circumference(s), the pressure shall be adjusted to the heat soak pressure without breaking contact between the heater plate and the pipe or fitting ends for a period equal to the heat soak time.

4.10 Jointing the pipe or fitting ends

On completion of the heat soak time, move the pipe or fitting ends from the heater plate. Then remove the heater plate and bring the heated pipe or fitting ends together within the maximum specified time limit in a controlled manner to apply the fusion jointing pressure which takes into account the drag pressure.

4.11 Cooling the pipe or fitting ends

The joint shall be held immobile under pressure in the butt fusion jointing machine for the period of time defined as the cooling time in the machine under pressure. The fusion jointing pressure (and in case of the dual low-pressure jointing procedure the cooling-cycle reduced pressure) shall be maintained in accordance with the procedure used.

Allowing appropriate time for cooling under pressure prior to removal from the machine clamps is important in order to develop strength and achieve joint integrity.

Further cooling may take place in the machine without pressure or out of the machine, particularly if working at higher temperatures than (23 ± 2) °C or when the joint is subjected to rough handling.

5 Butt fusion jointing procedures

5.1 General

The following three butt fusion jointing procedures are described in detail in 5.2 to 5.4:

— single low-pressure fusion jointing procedure;

— dual low-pressure fusion jointing procedure;

— single high-pressure fusion jointing procedure.

The dual low-pressure fusion jointing procedure is only applicable for pipes and spigot end fittings with a wall thickness greater than 22 mm.

NOTE For the purpose of this document the minimum cooling time under pressure, for all three butt fusion jointing procedures, is based on cooling to a mid-wall temperature of 80 °C (at an ambient temperature of (23 ± 2) °C).

5.2 Single low-pressure fusion jointing procedure

Butt fusion jointing conforming to the single low-pressure procedure shall be performed as specified in Table 1. Examples of values of parameters for the single low-pressure fusion jointing procedure are given in Annex A.

Table 1 — Phases, parameters and values for single low-pressure fusion jointing procedure

Phase (see Figure 1)	Parameter	Unit	Value
1 and 2	Heater plate temperature	°C	225 ± 10
1	Bead-up pressure	MPa	0,17 ± 0,02 + drag pressure[a]
	Minimum bead-up size	mm	$0,5 + 0,1 \times e_n$
2	Minimum heat soak time	s	$(13,5 \pm 1,5) \times e_n$
	Heat soak pressure	MPa	0 to drag pressure[b]
3	Maximum heater plate removal time	s	See ISO 12176-1
4	Maximum time to achieve fusion jointing pressure	s	$3 + 0,03 \times d_n$
	Fusion jointing pressure	MPa	0,17 ± 0,02 + drag pressure[a]
5	Minimum cooling time in the machine under pressure, for wall thickness < 18 mm	min	$e_n + 3$[c]
	Minimum cooling time in the machine under pressure, for wall thickness ≥ 18 mm	min	$0,015 \times e_n^2 - 0,47 \times e_n + 20$[c]
6	Minimum cooling time out of the machine	min	[d]

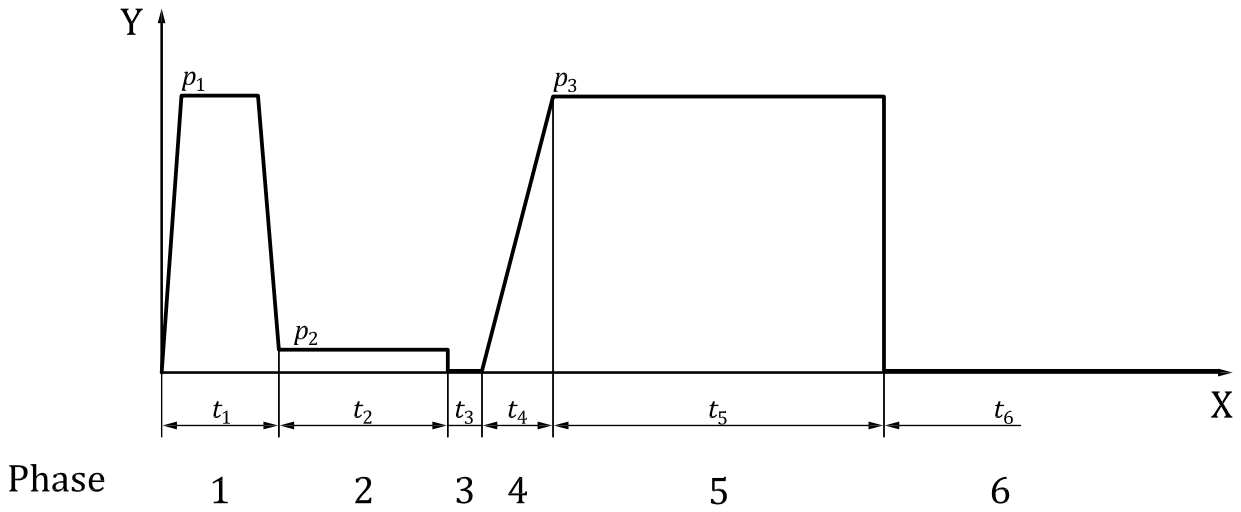
[a] See definition 3.5.

[b] Use the lowest possible pressure during the heat soak that will allow the pipe to remain in contact with the heater plate, up to a maximum of the current drag pressure.

[c] The minimum cooling time in the machine under pressure is $e_n + 3$ or $0,015 \times e_n^2 - 0,47 \times e_n + 20$ (depending on the wall thickness) at an ambient temperature of (23 ± 2) °C. This is the cooling time for the butt joint when still in the machine and under pressure. Cooling times may be shortened and should be lengthened depending on ambient temperatures (approximately 1 % per 1 °C).

[d] A cooling time out of the machine and before rough handling may be recommended.

Figure 1 illustrates the single low-pressure fusion jointing cycle, with an explanation of the individual elements of the fusion jointing cycle.



Key

X time
Y pressure
p_1 bead-up pressure
p_2 heat soak pressure
p_3 fusion jointing pressure
t_1 bead-up time
t_2 heat soak time
t_3 heater plate removal time
t_4 time to achieve fusion jointing pressure
t_5 cooling time in the machine under pressure
t_6 cooling time out of the machine

Figure 1 — Single low-pressure fusion jointing cycle

5.3 Dual low-pressure fusion jointing procedure

Butt fusion jointing conforming to the dual low-pressure procedure shall be performed as specified in Table 2. Examples of values of parameters for the dual low-pressure fusion jointing procedure are given in Annex B.

Table 2 — Phases, parameters and values for dual low-pressure fusion jointing procedure

Phase (see Figure 2)	Parameter	Unit	Value
1 and 2	Heater plate temperature	°C	232,5 ± 7,5
1	Bead-up pressure	MPa	0,15 ± 0,02 + drag pressure[a]
	Minimum bead-up size	mm	see Annex B
2	Minimum heat soak time	s	$10 \times e_n + 60$
	Heat soak pressure	MPa	0 to drag pressure[b]
3	Maximum heater plate removal time	s	≤ 10
4	Maximum time to achieve fusion jointing pressure	s	Not specified
5	Fusion jointing pressure	MPa	0,15 ± 0,02 + drag pressure[a]
	Fusion jointing time	s	10 ± 1
6	Cooling-cycle reduced pressure	MPa	0,025 ± 0,002 + drag pressure[a]
	Minimum cooling time in the machine under pressure	min	$0{,}015 \times e_n^2 - 0{,}47 \times e_n + 20$[c]
7	Minimum cooling time out of the machine	min	[d]

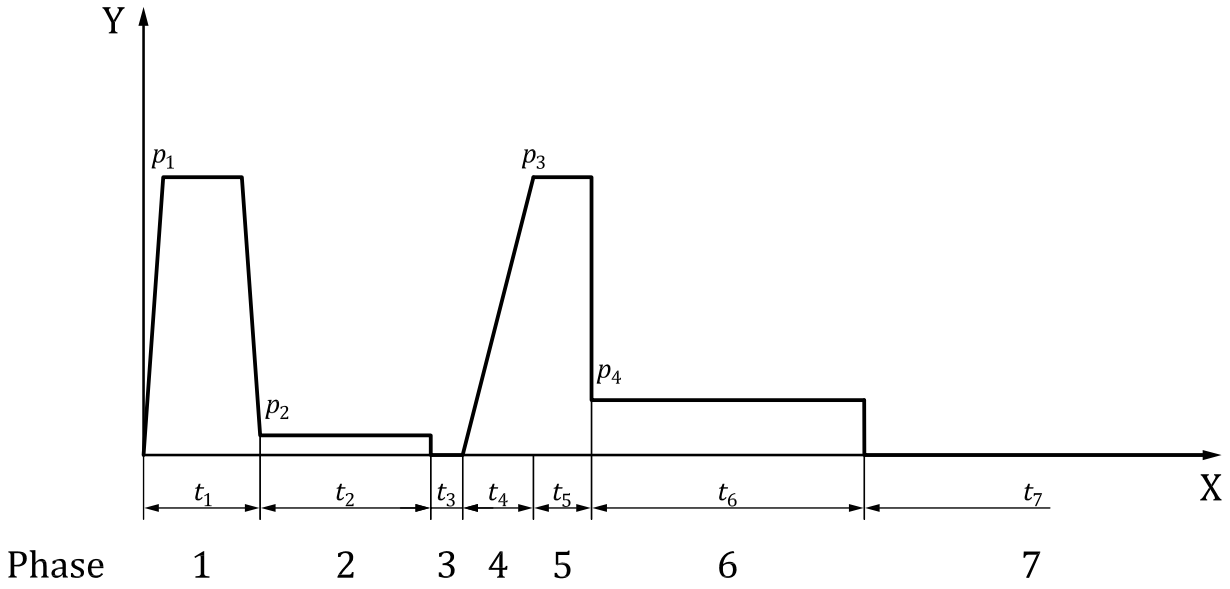
[a] See definition 3.5.

[b] Use the lowest possible pressure during the heat soak that will allow the pipe to remain in contact with the heater plate, up to a maximum of the current drag pressure.

[c] The minimum cooling time in the machine under pressure is $0{,}015 \times e_n^2 - 0{,}47 \times e_n + 20$ at an ambient temperature of (23 ± 2) °C. This is the cooling time for the butt joint when still in the machine and under pressure. Cooling times may be shortened and should be lengthened depending on ambient temperatures (approximately 1 % per 1 °C).

[d] A cooling time out of the machine and before rough handling may be recommended.

Figure 2 illustrates the dual low-pressure jointing pressure cycle, with an explanation of the individual elements of the fusion jointing cycle.



Key

X	time	t_1	bead-up time
Y	pressure	t_2	heat soak time
p_1	bead-up pressure	t_3	heater plate removal time
p_2	heat soak pressure	t_4	time to achieve fusion jointing pressure
p_3	fusion jointing pressure	t_5	fusion jointing time (bead roll-over time)
p_4	cooling-cycle reduced pressure	t_6	cooling time in the machine under pressure
		t_7	cooling time in machine without pressure or out of machine

Figure 2 — Dual low-pressure fusion jointing cycle

The dual low-pressure fusion jointing procedure follows the same principle for the single low-pressure fusion jointing procedure up to the moment the heater plate is removed. Then a fusion jointing pressure of 0,15 MPa shall be applied for 10 s after bringing the pipe or fitting ends together, to allow the melt on each surface to mix and a bead to form.

After the initial 10 s, the pressure shall be reduced to a fusion jointing pressure of 0,025 MPa during cooling.

5.4 Single high-pressure fusion jointing procedure

Butt fusion jointing conforming to the single high-pressure fusion jointing procedure shall be performed as specified in Table 3. Examples of values of parameters for the single high-pressure fusion jointing procedure are given in Annex C.

Table 3 — Phases, parameters and values for single high-pressure fusion jointing procedure

Phase (see Figure 3)	Parameter	Unit	Value
1 and 2	Heater plate temperature	°C	215 ± 15
1	Bead-up pressure	MPa	0,52 ± 0,1[a] + drag pressure[b]
2	Minimum heat soak time	s	(11 ± 1) × e_n
	Heat soak pressure	MPa	0 to drag pressure[c]
	Minimum bead size after heating	mm	1 + 0,15 × e_n
3	Maximum heater plate removal time	s	See ISO 12176-1
4	Maximum time to achieve fusion jointing pressure	s	Not specified
	Fusion jointing pressure	MPa	0,52 ± 0,1 + drag pressure[b]
5	Minimum cooling time in the machine under pressure	min	0,43 × e_n
6	Minimum cooling time out of the machine	min	[d]

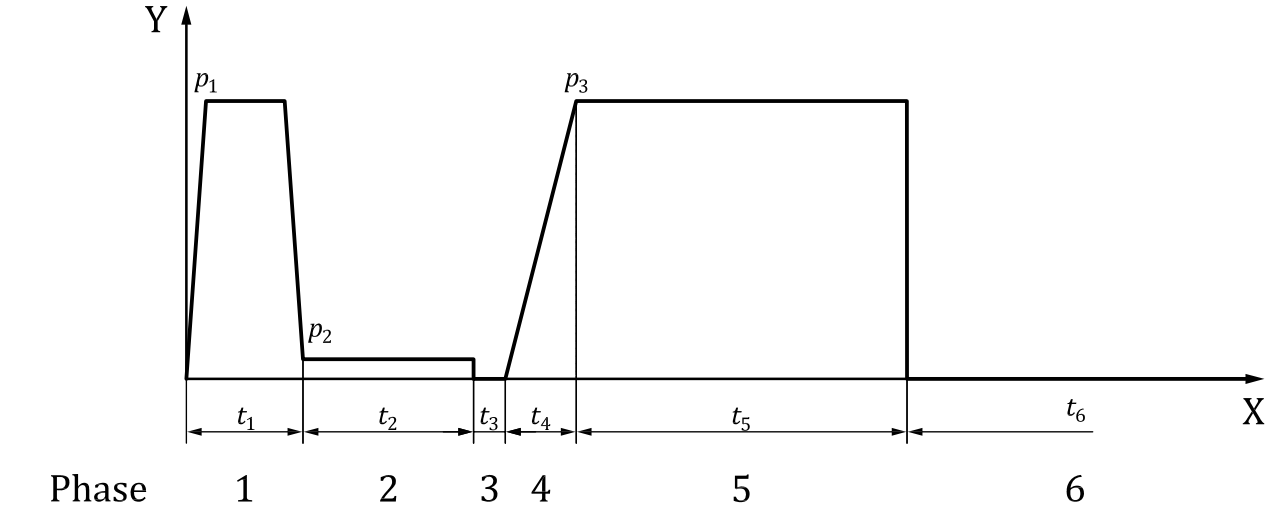
[a] Bead-up pressure is maintained until an indication of a bead completely around the circumference of both pipe ends is achieved. The pressure is then dropped for heat soak.

[b] See definition 3.5.

[c] Use the lowest possible pressure during the heat soak that will allow the pipe to remain in contact with the heater plate, up to a maximum of the current drag pressure.

[d] A cooling time out of the machine and before rough handling may be recommended.

Figure 3 illustrates the single high-pressure fusion jointing cycle, with an explanation of the individual elements of the fusion jointing cycle.



Key

X time
Y pressure
p_1 bead-up pressure
p_2 heat soak pressure
p_3 fusion jointing pressure
t_1 bead-up time
t_2 heat soak time
t_3 heater plate removal time
t_4 time to achieve fusion jointing pressure
t_5 cooling time in the machine under pressure
t_6 cooling time out of the machine

Figure 3 — Single high-pressure fusion jointing cycle

6 Quality control

6.1 General

To check that the correct welding parameters have been used reference should be made to the welding protocols or information held on data carriers.

The joints and associated fusion equipment shall be inspected for conformity. Destructive and/or non-destructive testing on joints may also be carried out to help give assurance that the quality of the joint is acceptable. Applicable test methods are given in 6.2 and 6.3. The results of each inspection should be recorded.

6.2 Destructive joint integrity testing

The butt fusion jointing procedures detailed in this document have been produced and validated through testing of sample joints. It is important to demonstrate the long-term integrity of fusion joints. Joint integrity testing is recommended as the quality control method for all fusion jointing procedures.

NOTE The following test methods can be used for the quality control of butt fusion procedures and joints:

— tensile testing in accordance with ISO 13953 (or another test in accordance with national or local standards);

— hydrostatic pressure testing at 80 °C for 1 000 h in accordance with ISO 1167-1, ISO 1167-3 and ISO 1167-4 (or another test in accordance with national or local standards);

— high-speed tensile testing in accordance with ASTM F2634 (or another test in accordance with national or local standards).

6.3 Non-destructive joint integrity testing

The fusion joint shall be examined visually and the fusion joint shall have:

— proper alignment with no part of the mating pipe having mismatch in excess of 10 % of the pipe wall thickness;

— a uniform double roll back bead that is consistent with the fusion procedure being used.

NOTE 1 The bead shapes (dimensions) can be different due to welding of PE components manufactured with materials of different melt mass flow rates (MFR), in accordance with ISO 1133-1[7].

In addition to the visual examination, a non-destructive joint integrity testing method might assist in determining whether the quality of the joint is acceptable.

NOTE 2 Examples of non-destructive joint integrity testing methods for the quality control of butt fusion joints are:

— Microwave;

— Ultrasonic;

— In some countries, the external bead is removed for further inspection where possible defects, such as contamination, result in bead separation which can be assessed by twisting the beads.

Annex A
(informative)

Examples of values of parameters for single low-pressure fusion jointing procedure

In Table 1 examples of parameters for single low-pressure fusion jointing procedure are given.

Table A.1 — Examples of parameters for single low-pressure fusion jointing procedure

Nominal outside diameter d_n	Nominal wall thickness e_n	Minimum bead-up size[a]	Minimum heat soak time[b]	Maximum heater plate removal time[c]	Maximum time to achieve fusion jointing pressure[d]	Minimum cooling time in machine under pressure[e]	Minimum cooling time out of the machine
mm	mm	mm	s	s	s	min	min
32	3,0	1	36 to 45	5	4	6	[f]
63	5,8	1	70 to 87	6	5	9	[f]
110	10,0	2	120 to 150	7	6	13	[f]
200	18,2	2	218 to 273	10	9	16	[f]
315	28,6	3	343 to 429	13	12	18	[f]
400	36,4	4	437 to 546	16	15	22	[f]
500	45,5	5	546 to 683	18	18	29	[f]
630	57,3	6	688 to 860	22	22	42	[f]
1 000	90,9	10	1 091 to 1 364	30	33	101	[f]

[a] The minimum bead-up size on the heater plate at the end of the bead-up time is $0,5 + 0,1 \times e_n$.

[b] The minimum heat soak time, in seconds, is $(12 \text{ to } 15) \times e_n$. It is highly recommended that heat soak times and heater temperatures at the upper end of the range be used in low ambient conditions.

[c] The heater plate removal time, in seconds, is according to ISO 12176-1. These times are a maximum. Every effort should be made to reduce these times wherever possible, to protect molten surfaces against rapid cooling.

[d] The maximum time to achieve fusion jointing pressure is $3 + 0,03 \times d_n$.

[e] The minimum cooling time in the machine under pressure is $e_n + 3$ or $0,015 \times e_n^2 - 0,47 \times e_n + 20$ (depending on the wall thickness) at an ambient temperature of (23 ± 2) °C. This is the cooling time for the butt joint when still in the machine and under pressure. Cooling times may be shortened and should be lengthened depending on ambient temperatures (approximately 1 % per 1 °C).

[f] A cooling time out of the machine and before rough handling may be recommended.

Annex B
(informative)

Examples of values of parameters for dual low-pressure fusion jointing procedure

In Table B.1 examples of parameters for dual low-pressure fusion jointing procedure are given.

Table B.1 — Examples of parameters for dual low-pressure fusion jointing procedure

Nominal outside diameter d_n	Nominal wall thickness e_n	Minimum bead-up size	Minimum heat soak time[a]	Cooling-cycle reduced pressure	Minimum cooling time in machine under pressure[b]	Minimum cooling time out of the machine
mm	mm	mm	s	MPa	min	min
250	22,7	2	285	0,025	17	c
315	28,6	3	346	0,025	19	c
400	36,4	3	424	0,025	23	c
500	45,5	3	515	0,025	30	c
630	57,3	3	633	0,025	42	c
710	64,5	3	705	0,025	52	c
800	72,7	3	787	0,025	65	c
900	81,8	3	878	0,025	82	c
1000	90,9	3	970	0,025	101	c

[a] The minimum heat soak time, in seconds, is $10 \times e_n + 60$. It is highly recommended that heater temperatures at the upper end of the range be used in low ambient conditions.

[b] The minimum cooling time in the machine under pressure is $(0{,}015 \times e_n^2 - 0{,}47 \times e_n + 20)$ at a pressure of 0,15 ± 0,02 MPa and an ambient temperature of (23 ± 2) °C. This is the cooling time for the butt joint when still in the machine and under pressure. Cooling times may be shortened and should be lengthened depending on ambient temperatures (approximately 1 % per 1 °C).

[c] A cooling time out of the machine and before rough handling may be recommended.

Annex C
(informative)

Examples of values of parameters for single high-pressure fusion jointing procedure

In Table C.1 examples of parameters for single high-pressure fusion jointing procedures are given.

Table C.1 — Examples of parameters for single high-pressure fusion jointing procedure

Nominal outside diameter d_n mm	Nominal wall thickness e_n mm	Minimum heat soak time[a] s	Minimum bead size after heating[b] mm	Maximum heater plate removal time[c] s	Minimum cooling time in machine under pressure min	Minimum cooling time out of the machine min
32	3,0	30 to 36	1	5	1	[d]
63	5,8	58 to 70	2	6	2	[d]
110	10,0	100 to 120	3	7	4	[d]
200	18,2	182 to 218	4	10	8	[d]
315	28,6	286 to 343	5	13	12	[d]
400	36,4	364 to 437	6	16	16	[d]
500	45,5	455 to 546	8	18	20	[d]
630	57,3	573 to 688	10	22	25	[d]
1 000	90,9	909 to 1 091	15	30	39	[d]

[a] The minimum heat soak time, in seconds, is $(11 \pm 1) \times e_n$. It is highly recommended that heat soak times and heater temperatures at the upper end of the range be used in low ambient conditions.

[b] The minimum bead size on the heater plate at the end of the bead-up time is $1 + 0{,}15 \times e_n$ and is generated through thermal expansion of the PE material only.

[c] The heater plate removal time, in seconds, is according to ISO 12176-1. These times are a maximum. Every effort should be made to reduce these times wherever possible, to protect molten surfaces against rapid cooling.

[d] A cooling time out of the machine and before rough handling may be recommended.

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