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Plastics pipes and fittings — Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems

Tubes et raccords en matières plastiques — Modes opératoires d'assemblage par soudage bout à bout de tubes et raccords en polyéthylène (PE) utilisés pour la construction de systèmes de distribution de gaz et d'eau

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 21307 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transports of fluids*, Subcommittee SC 4, *Plastics pipes and fittings for the supply of gaseous fuels*.

This second edition cancels and replaces the first edition (ISO 21307:2009), which has been technically revised.

Introduction

With the increasing use of bimodal polyethylene (PE) materials such as PE 80 and PE 100, more and more PE compounds are appearing on the pipe market accompanied by proposals for butt fusion procedures that often differ for the same materials. The aim of standardization is to encourage the use of similar procedures for similar materials. There is a need to examine current practice on a global scale and establish the best procedure(s) for the highest-quality, most reliable and efficient construction of PE butt fusion systems for gas and water distribution.

Plastics pipes and fittings — Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems

1 Scope

This International Standard establishes general principles regarding the procedure used in the construction and quality assessment of butt fusion joints incorporating fittings (ISO 8085-2) and pipes used in the construction of gas (ISO 4437) and water (ISO 4427) distribution systems made with equipment that complies with ISO 12176-1 and installed in accordance with ISO/TS 10839, relevant codes of practice, national regulations or industry guidance. Specifically, this International Standard specifies a number of proven butt fusion jointing procedures for pipes and fittings with a wall thickness up to and including 70 mm. This International Standard 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 It is important that pipe or fitting manufacturers and equipment manufacturers be consulted when undertaking butt fusion jointing of pipes with a wall thickness greater than 70 mm.

2 Normative references

The following referenced documents are indispensable for the application 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 1167-1, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 1: General method*

ISO 1167-3, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 3: Preparation of components*

ISO 1167-4, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 4: Preparation of assemblies*

ISO 4065, *Thermoplastics pipes — Universal wall thickness table*

ISO 4427 (all parts), *Plastics piping systems — Polyethylene (PE) pipes and fittings for water supply*

ISO 4437, *Buried polyethylene (PE) pipes for the supply of gaseous fuels — Metric series — Specifications*

ISO 8085-2, *Polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels — Metric series — Specifications — Part 2: Spigot fittings for butt fusion, for socket fusion using heated tools and for use with electrofusion fittings*

ISO/TS 10839, *Polyethylene pipes and fittings for the supply of gaseous fuels — Code of practice for design, handling and installation*

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

ISO 13953, *Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

ASTM F2634, *Standard test method for laboratory testing of polyethylene (PE) butt fusion joints using tensile-impact method*

3 Terms and definitions

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

3.1
cooling-cycle reduced pressure
reduced pressure, used in the cooling cycle of the dual low-pressure procedure after jointing time

3.2
cooling time in the machine under pressure
time period during which the butt fusion joint remains under pressure when still clamped in the machine

3.3
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

3.4
drag pressure
gauge pressure required to overcome, on a given machine, the sliding frictional drag force of the machine and pipe

3.5
fusion jointing pressure
actual pressure exerted on the pipe or fitting ends during jointing

3.6
gauge pressure
actual pressure read by the gauge of the butt fusion jointing machine

3.7
heater plate removal time
heater plate dwell 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

3.8
heater plate temperature
measured temperature on the surface of the heater plate where the pipe or fitting wall cross-section makes contact

3.9
heat soak pressure
pressure required to maintain the pipe or fitting in contact with the heater plate

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1) To be published. (Revises ISO 12176-1:2006)

3.10
heat soak time
time during which the heater plate is in contact with the pipe or fitting ends at the heat soak pressure

3.11
minimum bead size after heating
minimum value of bead size to be attained after completing the heat soak time

3.12
initial bead-up pressure
pressure exerted on the heater plate by the pipe or fitting ends during the bead-up phase of the jointing cycle, including drag pressure exerted on the pipe or fitting ends during jointing

3.13
initial bead-up time
time taken to generate a continuous bead, of a specified dimension, around the circumference of the ends of the pipes or fittings

3.14
initial bead-up size
bead size formed on the pipe or fitting ends during the bead-up phase

NOTE Initial bead-up size is expressed in millimetres.

3.15
fusion jointing time
⟨dual low-pressure⟩ time period allotted for bead roll-over before cooling-cycle reduced pressure

3.16
nominal wall thickness
e_{n}
wall thickness tabulated in ISO 4065, corresponding to the minimum wall thickness at any point e_{y}

NOTE Nominal wall thickness is expressed in millimetres.

3.17
operator
person authorized to build polyethylene (PE) systems from pipes and/or fittings, based on a written procedure agreed by the pipeline operator

3.18
pipeline operator
private or public organization authorized to design, construct and/or operate and maintain a pipeline supply system

4 Butt fusion jointing process

4.1 General

Polyethylene (PE) pipes for the production of butt fusion joints in accordance with this International Standard shall conform to ISO 4437 (alternatively ISO 4427). Fittings shall conform to ISO 8085-2.

Butt fusion joints in accordance with this International Standard shall be produced on equipment for fusion jointing PE systems conforming to ISO 12176-1.

4.2 Principle

The principle of butt fusion jointing is to heat two pipe or fitting ends by means of a heater plate to a designated temperature, then fuse them together by applying pressure and cool them under pressure for a designated time.

Butt fusion joints shall be made by qualified operators using butt fusion jointing machines that secure and precisely align the pipe ends. 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. 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 may be required to ensure proper alignment and the pipe support may also need to incorporate rollers to reduce drag pressure);

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 4.10.

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. 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.

Clean the planing unit and the heater plate surfaces with a clean lint-free cloth. Ensure heater is cold and power to unit is off.

For the dual low-pressure fusion jointing procedure, it is recomended that two dummy joints be made at the start of each jointing session to ensure removal of fine contaminant particles whenever the heater plate has been allowed to cool below 180 °C or for a size change.

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.

4.5 Planing the pipe or fitting ends

Plane the pipe or fitting ends to establish clean, parallel mating surfaces.

4.6 Aligning the pipes or fittings

Remove any shavings from the pipe or fitting ends. Clean the pipe or fitting ends with an alcohol wipe or dry cloth only if required by company, state or national standards.

Inspect the pipe or fitting ends for incomplete planing, voids or other imperfections, then bring them together to check for proper alignment. The pipe or fitting ends shall be rounded and aligned to ensure compliance with ISO/TS 10839, relevant codes of practice, national regulations or industry guidelines.

4.7 Measuring the drag pressure

Measure the gauge pressure required to overcome the frictional drag force of the machine and pipe. This pressure shall be added to the calculated bead-up and fusion jointing pressures.

4.8 Melting 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 procedure for the correct heater temperatures.

Install the heater plate in the butt fusion 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, 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.

4.9 Jointing the pipe or fitting ends

On completion of the heat soak time, pull the pipe or fitting ends from the heater plate. Then remove the heater plate and bring the molten pipe or fitting ends together within the specified time limits in a controlled manner. The joint shall be held at the jointing pressure(s) for the prescribed fusion jointing time(s).

4.10 Cooling the pipe or fitting ends

The molten 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. Allowing adequate time for cooling under pressure prior to removal from the machine clamps is important in order to develop strength and achieve joint integrity. The jointing pressure shall be maintained until the interface temperature has dropped below the re-crystalline melting temperature of the PE.

Further cooling may take place in the machine without pressure or out of the machine, particularly if working in high ambient temperatures.

5 Butt fusion jointing procedures

The following three butt fusion procedures are described in detail in 5.1 to 5.3:

— 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 with a wall thickness greater than 20 mm. The choice of fusion procedure shall be determined by the pipeline operator. Examples of single low-pressure, dual low-pressure, and single high-pressure fusion jointing procedures are given in Annex A.

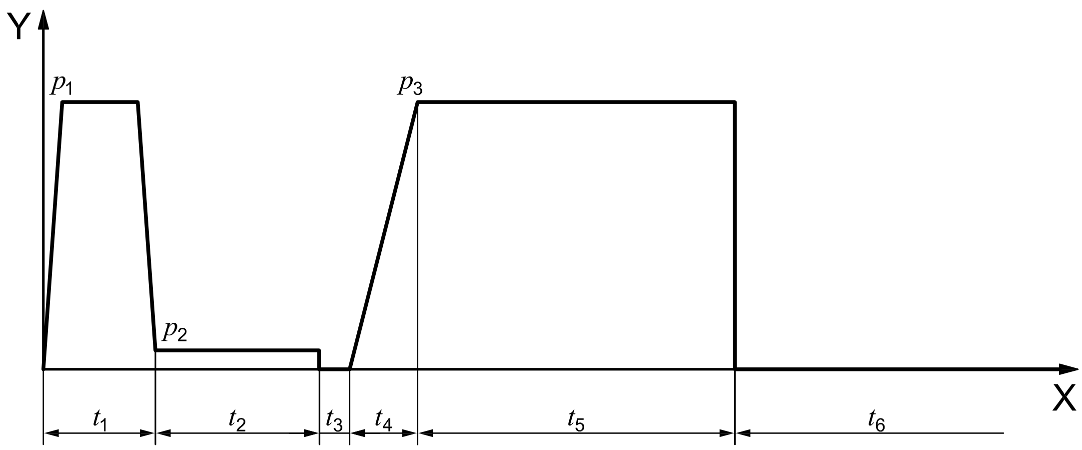
5.1 Single low-pressure fusion jointing procedure

Butt fusion jointing conforming to the single pressure and low fusion jointing pressure procedure shall be performed as specified in Table 1.

Table 1 — Parameters and values for single low-pressure fusion jointing procedure

Parameter	Unit	Value
Heater plate temperature	°C	200 to 245
Initial bead-up pressure	MPa	0,17 ± 0,02
Minimum initial bead-up size	mm	$0{,}5 + 0{,}1\ e_n$ [a]
Minimum heat soak time	s	$(11 \pm 1)\ e_n$
Heat soak pressure	MPa	0 to drag pressure
Maximum heater plate removal time	s	$0{,}1\ e_n + 4$
Fusion jointing pressure	MPa	0,17 ± 0,02
Maximum time to achieve interfacial pressure	s	$0{,}4\ e_n + 2$
Minimum cooling time in the machine under pressure	min	$e_n + 3$
Minimum cooling time out of the machine	min	$e_n + 3$
[a] Maximum 6 mm.		

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

t_1 initial 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

p_1 initial bead-up pressure

p_2 heat soak pressure

p_3 fusion jointing pressure

Figure 1 — Single low-pressure fusion jointing cycle

5.2 Dual low-pressure fusion jointing procedure

Butt fusion jointing conforming to the dual low-pressure jointing pressure procedure shall be performed as specified in Table 2.

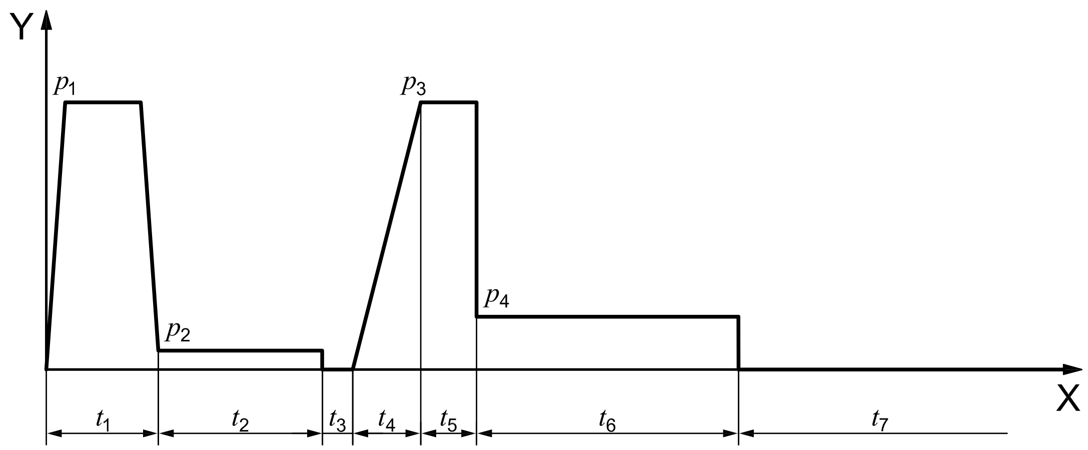
Figure 2 illustrates the dual low-pressure jointing pressure cycle, with an explanation of the individual elements of the fusion jointing cycle.

Table 2 — Parameters and values for dual low-pressure fusion jointing procedure

Parameter	Unit	Value
Heater plate temperature	°C	230 (+10, −5)
Initial bead-up pressure	MPa	0,15 ± 0,02
Minimum initial bead-up size	mm	$0{,}5 + 0{,}1\ e_n$ [a]
Minimum heat soak time	s	$10\ e_n + 60$
Heat soak pressure	MPa	0 to drag pressure
Maximum heater plate removal time	s	⩽10
Fusion jointing pressure	MPa	0,15 ± 0,02
Fusion jointing time	s	10 ± 1
Cooling-cycle reduced pressure	MPa	(0,025 ± 0,002) [b]
Minimum cooling time in the machine under reduced pressure	min	See Table A.2
Minimum cooling time out of the machine	min	See Table A.2

[a] Not exceeding 6 mm.

[b] If the wall thickness is above 20 mm.



Key

X time

Y pressure

t_1 initial bead-up time

t_2 heat soak time

t_3 heater plate removal time

t_4 time to achieve fusion jointing pressure

t_5 fusion jointing time (bead roll-over time)

t_6 cooling time in the machine under reduced pressure

t_7 cooling time in machine without pressure or out of machine

p_1 initial bead-up pressure

p_2 heat soak pressure

p_3 fusion jointing pressure

p_4 cooling-cycle reduced pressure

Figure 2 — Dual low-pressure fusion jointing cycle

The dual low-pressure cycle follows the same principle for single low-pressure fusion jointing 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 pressure of 0,025 MPa (excluding drag pressure) during cooling.

5.3 Single high-pressure fusion jointing procedure

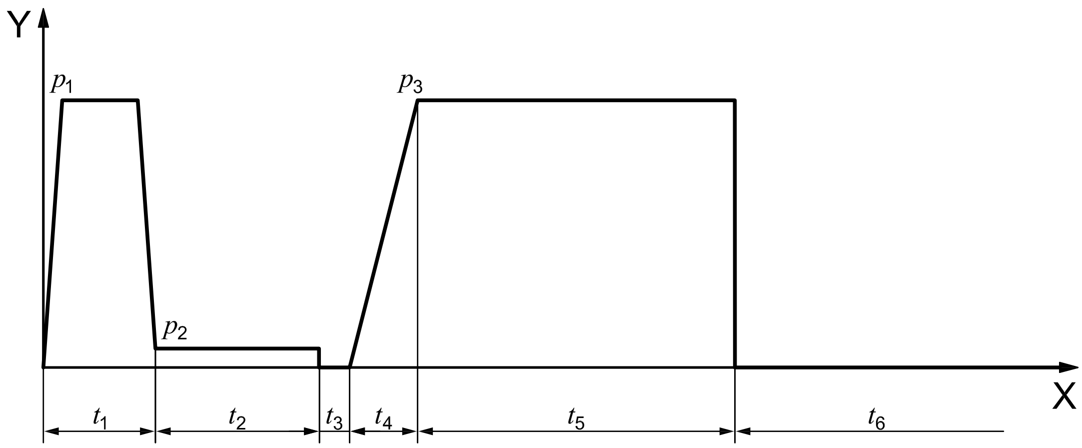
Butt fusion jointing conforming to the single high-pressure procedure shall be performed as specified in Table 3. This procedure is standardized for pipes or fittings with a wall thickness of minimum 5 mm up to and including 70 mm.

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

Table 3 — Parameters and values for single high-pressure fusion jointing procedure

Parameter	Unit	Value
Heater plate temperature	°C	200 to 230
Initial bead-up fusion jointing pressure	MPa	0,52 ± 0,1
Minimum heat soak time	s	$(11 \pm 1) \times e_n$
Minimum bead size after heating	mm	$0,15\ e_n + 1$
Heat soak pressure	MPa	0 to drag pressure
Maximum heater plate removal time	s	$0,1\ e_n + 8$
Fusion jointing pressure	MPa	0,52 ± 0,1
Minimum cooling time in the machine under pressure	min	$0,43\ e_n$
Minimum cooling time out of the machine	min	[a]

[a] A cooling time out of the machine and before rough handling may be recommended, but in most cases is not necessary with these cooling times.



Key

X time

Y pressure

t_1 initial 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

p_1 initial bead-up pressure

p_2 heat soak pressure

p_3 fusion jointing pressure

Figure 3 — Single high-pressure fusion jointing cycle

6 Quality control

6.1 General

The pipes, fittings and associated equipment may be inspected for conformity with the installation procedure.

The inspection may be carried out by the personnel engaged in jointing. Additional inspections may be carried out by a competent person at a frequency depending on the conditions of use. The results of each inspection may be recorded.

Destructive testing on joints performed in the field may also be carried out to ensure that the quality conforms to the fusion jointing procedure. Applicable test methods are given in 6.2.

6.2 Joint integrity testing

The butt fusion procedures detailed in this International Standard have been produced and validated through thorough testing of sample joints. It is extremely important to demonstrate the long-term integrity of fusion joints. Joint integrity testing is recommended as the quality control method for all fusion procedures and especially those not covered in Tables A.1 and A.2. Established butt fusion joint integrity test methods are available.

The following test methods are considered applicable for the quality control of butt fusion 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 quality control procedures

It is also recommended that simple on-site quality assurance systems be used to assess joint quality. This can be through the assessment of weld bead width and shape which should be within identifiable, prescribed limits depending on the PE material and environmental conditions. In some countries, the external bead is removed for further inspection where possible defects, such as contamination, result in bead separation.

Consideration should be given to the assessment of joint quality through non-destructive means. While it is recognized that conventional non-destructive methods, such as radiography and ultrasonics, might not detect all the possible faults that can occur in butt joints, they can detect areas of contamination and voiding. Consideration should be given to the use of such techniques to generate confidence in the butt fusion process.

Annex A
(informative)

Examples of single low-pressure, dual low-pressure and single high-pressure procedures

A.1 Single low-pressure fusion jointing procedure

Table A.1 — Single low-pressure fusion jointing procedure examples

Nominal wall thickness e_n mm	Minimum initial bead-up size[a] [a] mm	Minimum heat soak time[b] s	Maximum heater plate removal time[c] s	Maximum time to achieve interface fusion pressure[d] s	Cooling time in machine under pressure[e] min
4,5	1	45 to 54	5	3 to 4	8
7	1	70 to 84	5	4 to 6	10
12	2	120 to 144	5	6 to 8	15
19	2	190 to 228	6	8 to 11	22
26	3	260 to 312	7	11 to 14	29
37	4	370 to 444	8	14 to 19	40
50	6	500 to 600	9	19 to 25	53
70	6	700 to 840	11	25 to 35	73

[a] The minimum initial bead-up size on the heater plate at the end of the bead-up time = 0,5 + 0,1 e_n (maximum 6 mm).

[b] The minimum heat soak time, in seconds, is $(11 \pm 1) \times e_n$ (when heating up with a heat soak pressure less than 0,025 MPa). For the dual-pressure procedure, the minimum heat soak time is $10\, e_n + 60$. The recommended maximum heat soak time is $15\, e_n + 60$. It is highly recommended that heat soak times and heater temperatures at the upper end of the range be used in low ambient conditions. This results in larger weld beads and requires longer cooling times. Cooling time should be increased by doubling the increase in heat soak time (above the minimum) with two thirds of the increase in cooling time under pressure.

[c] The heater plate removal time, in seconds, is $0,1\, e_n + 4$. 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 $0,4\, e_n + 2$.

[e] The cooling time in the machine under pressure is $e_n + 3$, at a pressure of 0,17 MPa. This is the cooling time for the butt joint when still in the machine and under pressure. Cooling times may require lengthening or shortening depending on ambient temperatures.

A.2 Dual low-pressure fusion jointing procedure

Table A.2 — Examples of dual low-pressure fusion jointing procedure

Nominal wall thickness[a] e_n mm	Bead-up interface stress MPa	Minimum heat soak time s	Fusion and cooling interface stress (first 10 s) MPa	Cooling interface stress (after 10 s) MPa	Cooling time in machine under pressure min
20,1	0,15	260	0,15	0,025	15
22,7	0,15	285	0,15	0,025	15
25,4	0,15	315	0,15	0,025	15
28,3	0,15	345	0,15	0,025	15
32,3	0,15	385	0,15	0,025	15
36,4	0,15	425	0,15	0,025	20
41,0	0,15	470	0,15	0,025	20
45,5	0,15	515	0,15	0,025	20
50,8	0,15	570	0,15	0,025	20
57,2	0,15	635	0,15	0,025	25

[a] For all thickness welds, the following parameters apply: an initial bead size of 3 mm, a minimum soak interface stress of 0 MPa, a maximum plate removal time of 10 s, and a recommended additional cooling time out of clamps of 50 % of cooling time under pressure.

A.3 Single-pressure and high-fusion jointing pressure procedure

Table A.3 — Examples of single-pressure and high-fusion jointing pressure procedure

Nominal wall thickness e_n mm	Heat soak pressure[a] MPa	Minimum bead size after heating[c] mm	Minimum heat soak time[d] s	Maximum heater plate removal time[e] s	Fusion and cooling interface pressure[b] MPa	Cooling time in machine under pressure[f] min
5	0 to drag pressure	1	50 to 60	8	0,52	2,5
9	0 to drag pressure	2	90 to 108	10	0,52	4
14	0 to drag pressure	3	140 to 168	15	0,52	6
30	0 to drag pressure	5	300 to 360	20	0,52	13
70	0 to drag pressure	11	700 to 840	20	0,52	30

[a] No pressure is applied, but a value equal to drag may be applied to maintain contact between pipe ends and the heater plate.

[b] Interface contact pressure may be applied for a time sufficient to ensure good thermal contact between pipe ends and the heater plate as evidenced by an indication of a bead around the circumference of both pipe ends before dropping the pressure to drag.

[c] Minimum bead size, in millimetres, is $(0{,}15 \times e_n) + 1$, and is generated through thermal expansion of the PE material only. Once the required bead size and minimum soak time are achieved, pipe ends are separated, the heater plate is removed and the pipe ends are brought together under the fusion jointing pressure. These values are a minimum and can be increased. However, this would inevitably increase joint cooling times.

[d] The minimum heat soak time, in seconds, is $(11 \pm 1) \times e_n$ (heating up with a heat soak pressure as prescribed). The recommended minimum heat soak time, in seconds, is $(11 \times e_n) + 60$. It is highly recommended that heat soak times and heater temperatures at the upper end of the range be used in low ambient conditions. This results in larger weld beads and may require longer cooling times.

[e] Heater plate removal time is $(0{,}1 \times e_n) + 8$. These times are a maximum. Every effort should be made to reduce these times wherever possible to protect molten surfaces against rapid cooking.

[f] This is the cooling time for the butt joint when still in the machine and under pressure. This is based on a cooling time of 0,43 min per mm of wall thickness. A further cooling time out of the machine and before rough handling may be recommended but in most cases is not necessary with these cooling times.

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