TECHNICAL SPECIFICATION

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Polyethylene pipes and fittings for the supply of gaseous fuels — Code of practice for design, handling and installation

Tubes et raccords en polyéthylène pour le transport de combustibles gazeux — Code de pratique pour la conception, la manutention et l'installation

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 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 second edition cancels and replaces the first edition (ISO/TS 10839:2000), which has been technically revised.

The main changes are as follows:

— the whole document has been redrafted in order to improve its readability;

— clauses referring to the jointing processes have been transformed into normative annexes (see Annex A, Annex B and Annex C);

— the Scope has been updated to include hydrogen;

— Clause 2 and Clause 3 have been updated;

— various additional updates and corrections have been made throughout the document to reflect the current state of the art;

— information on socket fusion jointing procedures has been deleted as this is the subject of other published documents (see Annex D).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Polyethylene pipes and fittings for the supply of gaseous fuels — Code of practice for design, handling and installation

1 Scope

This document presents a code of practice dealing with polyethylene (PE) pipes and fittings for buried pipeline systems outside buildings, conforming to the ISO 4437 series, and designed to transport gaseous fuels [as defined in ISO 4437-1, e.g. methane, liquified petroleum gas (LPG), manufactured gas and hydrogen] within the temperature range −20 °C to +40 °C. This document also gives appropriate temperature-related requirements.

The code of practice covers mains and service lines whose components are prepared for fusion or mechanical jointing. It also gives instructions for the design, storage, handling, transportation, laying conditions and fusion quality control of PE pipes and fittings as well as subsequent joint testing, backfilling, pipe system testing and commissioning.

NOTE For the renovation code of practice, reference is made to the ISO 11299 series and to ISO 11295 for classification and to the ISO 21225 series for further information for trenchless replacement.

The minimal requirements for the jointing methods are given in:

— Annex A (butt fusion);

— Annex B (electrofusion); and

— Annex C (mechanical jointing).

In some countries the use of heated-tools socket and saddle fusion is permitted; information on heated-tools fusion jointing techniques is given in Annex D.

In the case of ground movement or shaking (e.g. earthquakes, etc.) it can be necessary to implement precautions mentioned in this document following guidelines provided by authorities (e.g. Eurocode 8,[7] EN 12007-1:2012, Annex A,[8] etc.),

Workers' health and safety issues are outside the scope of this document.

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 4437-1, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 1: General*

ISO 4437-2:2014, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 2: Pipes*

ISO 4437-3, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 3: Fittings*

ISO 4437-4, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 4: Valves*

ISO 4437-5, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 5: Fitness for purpose of the system*

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

ISO 12176-2, *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 2: Electrofusion*

ISO 12176-3, *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 3: Operator's badge*

ISO 12176-4, *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 4: Traceability coding*

ISO 12176-5, *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 5: Two-dimensional data coding of components and data exchange format for PE piping systems*

ISO 13950, *Plastics pipes and fittings — Automatic recognition systems for electrofusion joints*

ISO 17885:2021, *Plastics piping systems — Mechanical fittings for pressure piping systems — Specifications*

EN 12327, *Gas infrastructure — Pressure testing, commissioning and decommissioning procedures — Functional requirements*

3 Terms, definitions and abbreviated terms

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

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

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

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

3.1 Terms and definitions

3.1.1
butt fusion machine pressure
pressure indicated on the gauge or on a pressure display on a butt fusion machine, giving an indication of the interface force applied to the pipe and/or fitting ends

3.1.2
clearance
shortest distance between the outer limits of two objects

3.1.3
drag resistance
frictional resistance due to the weight of the length of pipe fixed in the moveable clamp at the point at which movement of the moveable clamp is initiated (peak drag), or the friction occurring during movement (dynamic drag)

3.1.4
electrofusion control unit
equipment implementing the output fusion parameters of voltage or current and time or energy to execute the fusion cycle as specified by the electrofusion fitting manufacturer

3.1.5
frictional losses in the butt fusion machine
force necessary to overcome friction in the whole mechanism of a butt fusion machine

3.1.6
fusion operator
person trained to carry out fusion jointing between polyethylene (PE) pipes and/or fittings

Note 1 to entry: Fusion jointing is based on a written procedure agreed by the pipeline operator

Note 2 to entry: The fusion operator is trained for one or more fusion–jointing procedures

3.1.7
interface force
force between the fusion surfaces of the pipe(s) and/or fitting(s) during the fusion cycle, as specified in the fusion diagram

3.1.8
operator
person authorized to build polyethylene (PE) systems from pipes and/or fittings, based on a written procedure agreed by the pipeline operator

3.1.9
overall service (design) coefficient
C
overall coefficient, with a value greater than 1, which takes into consideration service conditions as well as properties of the components of a piping system

3.1.10
pipeline operator
private or public organization authorized to design, construct and/or operate and maintain a gas supply system

3.1.11
soil cover
vertical distance between the top of a buried pipe and the normal surface after finishing work

EXAMPLE Including pavement.

3.2 Symbols and abbreviated terms

A	depth
a	correct bead root
B	bead width
B_m	average bead width
b	rejected bead root
C	overall service (design) coefficient
D_F	temperature derating coefficient
d_e	external diameter of pipe or spigot fitting
EF	electrofusion
e_n	pipe or fitting nominal wall thickness
F	maximum drag force (N)
L	insertion depth

MOP maximum operating pressure

MPa megapascal

MRS minimum required strength

N Newton

p pressure

p_{RCP} critical rapid crack propagation pressure

RCP rapid crack propagation

SDR standard dimension ratio

SF safety factor

t time

UV ultraviolet

V misalignment

WPS welding procedure specification

σ maximum tensile stress (MPa)

σ_y tensile stress at yield (MPa)

4 Design

4.1 General

A written laying procedure, authorized by the pipeline operator, shall be made available prior to the construction of a pipeline. The laying procedure shall include specification of the jointing procedure (butt fusion, or electrofusion, or mechanical), the pipe and fitting materials to be used, the trenching and backfilling requirements, the pressure testing and commissioning requirements, and the data to be collected for the traceability system.

The selection of materials, standard dimension ration (SDR) series, dimensions and assembling techniques shall be the responsibility of the pipeline operator.

There are two SDR series in common use for gas supply systems: SDR 17 and SDR 11. Other SDR series can also be used, such as SDR 26 for renovation.

The training and the level of skill of the operator(s) shall be in accordance with the requirements of the jointing procedures.

General guidelines for supervision and quality control are given in Clause 6.

NOTE Information on the suitability of pipes made from PE100-RC for trenchless technologies is given in ISO 4437-1 and EN 1555-1.[9]

4.2 Material, components and jointing equipment

The PE materials and components used shall conform to ISO 4437-1, ISO 4437-2, ISO 4437-3, ISO 4437-4, ISO 4437-5 and ISO 17885. Other components not covered by the above-mentioned International Standards shall conform to the relevant national standards or in the absence of such documents, the components shall meet the performance requirements of the system as demonstrated by the manufacturer.

The fusion equipment used for the construction of the pipeline shall conform to the requirements of ISO 12176-1 or ISO 12176-2. If the operation of the fusion equipment requires an operator's badge, the badge shall conform to ISO 12176-3. Traceability of PE materials shall refer to ISO 12176-4 and/or ISO 12176-5.

4.3 Maximum operating pressure

The maximum operating pressure (MOP) of the system shall be selected by the pipeline operator on the basis of the gas supply system operating requirements and the materials used. The MOP of a PE system depends on the type of resin used (the minimum required strength, MRS), the pipe SDR series and the service conditions, and is limited by the overall service (design) coefficient, C, and the rapid crack propagation (RCP) criteria.

The overall service (design) coefficient C for thermoplastics materials should be as specified in ISO 12162. This coefficient is used to calculate the MOP of the pipeline. C shall be greater than or equal to 2 for PE pipeline systems for natural gas. For other gases, a higher C value according to ISO 4437-1:2012, Annex A, can be defined.

The MOP shall be calculated using Formula (1):

$$MOP = \frac{20 \times MRS}{C \times (SDR - 1) \times D_{\mathrm{F}}} \qquad (1)$$

NOTE The temperature derating coefficient, D_{F}, is used in the calculation of the MOP which takes into account the influence of the operating temperature.

The temperature derating coefficient, D_{F}, for various operating temperatures is given in Annex E.

The ratio of the critical RCP pressure, p_{RCP}, to the MOP shall be ≥ 1,5 at the minimum operating temperature. The critical RCP pressure, p_{RCP}, is dependent upon temperature, pipe size, SDR and type of PE material used. It is defined in accordance with ISO 4437-1 and ISO 4437-2, which specify a test temperature of 0 °C.

Where the pipe operating temperature decreases below 0 °C, the p_{RCP}/MOP ratio shall be recalculated using a p_{RCP} value determined from the minimum expected operating temperature of the pipe. If necessary, the value of the MOP shall be reduced so as to maintain the p_{RCP}/MOP ratio at a value ≥ 1,5.

4.4 Assembly techniques

Jointing procedures may vary depending upon the type of PE material and the pipe size used. Butt fusion and electrofusion are the preferred jointing methods. For the butt fusion jointing procedure, a reference to ISO 21307 is useful.

For electrofusion and heated-tools socket fusion processes including the operation of fusion control units, refer to the manufacturers of these components including the control units.

For fusion joints, evidence of the fusion compatibility between the jointing materials should be given.

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 fusion operator, and the quality control methods to be used.

4.5 Squeeze-off properties

When squeeze-off techniques are considered, the suitability of the pipe for squeeze-off shall be confirmed in accordance with ISO 4437-2:2014, Annex C.

5 Construction

5.1 Competences

Operators shall be competent in the field of the assigned job. Operators shall possess the necessary skills and required knowledge and the ability to operate with awareness.

NOTE 1 Specific courses provide training for the competencies that can be certified by a third party organization operating, for example, in accordance with ISO/IEC 17020.

NOTE 2 An example of a specific training course for fusion operators can be found in ISO/TR 19480.

5.2 Storage, handling and transport

5.2.1 General

PE pipes are available in coils, drums or straight lengths. Fittings are normally individually packed. Mishandling of the pipes and fittings shall be avoided to protect them against gouges, scratches, cuts, holes, kinks or flattening.

5.2.2 Storage

PE pipes can be stored outside and under UV radiation provided that requirements for the resin as stated in ISO 4437-1 are met. Coloured pipes (e.g. yellow or orange) can be subject to degradation if solar UV radiation exceeds values as given in ISO 4437-1:2014, Table 2. The user of this document should consider information of the pipe manufacturer for allowable UV radiation dose with determined regional UV radiation level during storage.

NOTE 1 Information on regional levels of UV radiation may be found on web pages of national authorities e.g. meteorological institutes.

NOTE 2 ISO 4437-1 resistance to weathering is based on a cumulative exposure of 3,5 GJ/m^2 UV radiation level

Coloured pipes which have been stored outdoor uncovered for longer than recommended by the manufacturer shall only be used if tested in accordance with Table 1.

Table 1 — Minimum tests for evaluating coloured pipes when over-exposed to UV radiation

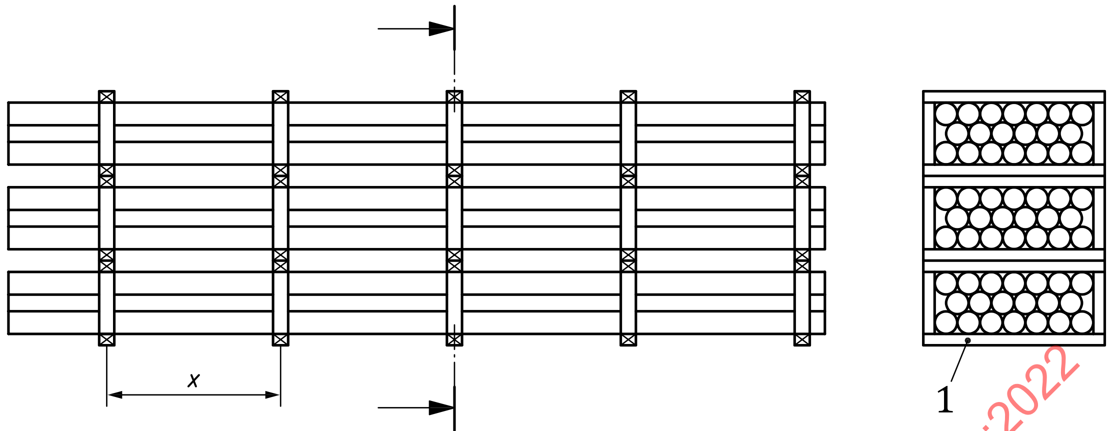
Test	Source and method
Elongation at break (all wall thicknesses)	ISO 4437-2:2014, Table 4
Hydrostatic strength (80 °C, 1 000 h)	ISO 4437-2:2014, Table 4
Decohesive resistance	ISO 4437-5:2014, Table 5

PE fittings and valves can be stored following the manufacturer's recommendation.

Straight pipes shall be stacked on a suitable surface, preferably flat and free from stones or other projections or sharp objects likely to deform or damage the pipes. Pipes and fittings shall be stored in such a way as to minimize the possibility of the material being damaged by crushing or piercing.

The distances “*x*” (Figure 1) between support frames holding packs of pipes together shall be equal in order to allow the frames to be stacked.

The support frame shall not be nailed together and should be constructed in such a way that the load is directly supported by the frame and not by the pipes.



Key

x distance between supports

1 support frame

Figure 1 — Support frame

The exact height to which straight pipes can be stacked depends on many factors such as material, size, wall thickness and ambient temperature. Stacking shall avoid distortion of pipes over the limits as given by the manufacturer during the storage. The manufacturer's stacking recommendations shall be followed.

PE pipes may be coiled or wound on drums. Coils of large-diameter pipes with d_e ≥ 110 mm shall be stored vertically in purpose-built racks or cradles. Where loose straight pipes are stacked in pyramidal fashion, this shall not exceed a height of 1 m. Fittings shall be stored in their original packaging until being prepared for use. Contact with aggressive reagents or solvents shall be avoided.

The pipes with the earliest extrusion date should be used first for installation. The fittings with the earliest manufacturing date should be used first for installation. Guidance from the product manufacturer should be considered.

5.2.3 Handling

Initial handling of straight pipes shall be made with the pipes as delivered by the manufacturer (e.g. in their own packaging), thus minimizing damage during this phase. When loading, unloading or handling, it is preferable to use mechanical equipment to move or stack the packages. The pipes shall not be dragged or thrown along the ground. If handling equipment is not used, choose techniques which are not likely to damage the pipes and/or fittings.

Coils of pipe stacked on pallets are easily handled using a forklift truck. Individual coils shall not be rolled off the edge of a vehicle load platform. Coils shall be slung individually when off-loading with a crane. Before laying a pipe, ensure that the drum is positioned correctly and that its axle will remain stable during the unrolling operation. While unrolling, ensure that the pipe is not damaged.

Fittings and valves shall be handled in accordance with manufacturer instructions and left in original packaging until use.

5.2.4 Transport

When transporting straight pipes, flatbed vehicles shall be used. The bed shall be free from nails and other protuberances. The pipes shall rest uniformly on the vehicle over their whole length, and shall be securely held in place during transport.

Coiled pipes shall be transported stacked on a pallet or as individual coils, and be firmly secured to the vehicle. The height of the top of a drum when loaded on a vehicle shall take into consideration the local regulations on the maximum height and any limitations expected on the route. Drums shall be firmly secured to the vehicle.

Fittings and valves shall be transported in accordance with manufacturer instructions.

5.3 Jointing

The jointing operation, either mechanical or fusion, shall be performed in accordance with the pipeline operator's written procedure. The minimal jointing requirements, given in Annex A, Annex B and Annex C, shall be respected.

The fusion procedure specification shall take into account the relevant fusion standards, if existing, and any recommendation from the pipe, fitting and accessory manufacturers.

NOTE 1 The relevant International Standard for butt-fusion jointing procedure is ISO 21307.

NOTE 2 In some countries "fusion procedure specification" is also defined as "welding procedure specification (WPS)"

PE pipes, fittings and accessories may be jointed either by heated-tool fusion jointing, electrofusion jointing or mechanical jointing. The jointing and quality control methods used for the construction of the gas supply system shall be appropriate to the design of the network.

Fusion operators shall possess the necessary skill and knowledge and ability to produce joints of consistently high quality. To this end, they shall receive formal training under the supervision of a qualified instructor.

The gas company can require evidence of training or qualification for fusion.

NOTE 3 An example of formal training and assessment can be found in ISO/TR 19480.

The same level of skill, knowledge and ability is required for mechanical jointing. The gas company can require evidence of training or qualification. When tightening or untightening a mechanical joint, it is essential that torsional stress is not transmitted to the pipe.

5.4 Laying

5.4.1 General

Care shall be taken to prevent damage to the pipes and fittings during the whole of the laying process.

Changes in direction of a PE pipeline when laying can be made using pre-formed bends or elbow fittings or by making use, within limits, of the natural flexibility of the pipe. Natural flexibility may be used for bend radii ≥ 25 × d_e, and also for smaller radii for certain SDR values and materials, provided that this is consistent with operational experience and good engineering practice.

NOTE 1 In general, the flexibility is a factor of SDR, environmental temperature and material. The pipe manufacturer can be consulted for additional guidance or instructions.

NOTE 2 Information on the bend radii for mechanical joints are given in Annex C.

The flexibility of PE pipes is reduced in cold weather. If the temperature falls below −15 °C for straight pipes and for fittings, or below 0 °C for coiled pipes, special handling instructions, issued by the manufacturers, shall be followed.

Machine-bending of pipes or bending after the application of heat in the fields shall not be used.

Where PE pipes, fittings and valves are allowed to be installed above ground they shall be protected against mechanical damage and, in case of non-black pipes, UV degradation.

If the gas pipeline isn't protected by the surrounding soil, special consideration should be taken to reduce any kind of risk, e.g. ignition sources, high temperatures, etc.

The minimum clearance between the pipe and obstacles (e.g. utilities, structures or immovable rocks) shall be 200 mm from the pipe surface. If this minimum clearance cannot be observed, a protection barrier shall be installed. Special precautions shall be taken if the gas pipeline crosses or is laid alongside other buried services, e.g. a hot water or steam pipeline, a petrol-carrying pipe, a petrol station or a high-voltage cable, etc.

Stresses caused by differences in temperature between laying and operation shall be taken into consideration. The position of the pipeline shall be recorded before backfilling.

To minimize the possibility of damage to the pipeline by external influences, at least one of the following measures shall be considered:

a) place a warning device, for example a protection tile hazard tape, etc. along the top of the pipe;

b) place a tracer wire to enable the pipe to be located again in future;

c) install permanently visible above-ground markings, especially at road, railway and water crossings, at blow-off devices, on private land, at boundaries between plots of land, and at points where the pipeline changes direction.

5.4.2 Trench

Excavating and backfilling of the trench shall be in accordance with the written procedure authorized by the pipeline operator. The width of the trench bottom shall be large enough to allow correct installation and backfilling.

If it should be necessary to perform any fusion jointing in the trench, the width of the trench can need to be larger, depending on the type of fusion jointing and the type of equipment used.

Pipes may be laid in the trench without preparation of the bottom, if this consists of relatively soft, fine-grained soils free of large and sharp-edged stones and other hard objects, and where the bottom of the trench can readily be brought to an even finish providing uniform support for the pipes over their whole length.

5.4.3 Drag forces

Pipes shall not be overstressed by tensile forces during laying. If the pipe is laid by drag, care shall be taken that the drag force is not greater than the values given by Formula (2) and Formula (3):

$$F = \frac{\sigma \times \pi \times d_e^2}{SF \times SDR} \qquad (2)$$

$$\sigma = \frac{\sigma_y}{1,25} \qquad (3)$$

where:

F is the maximum drag force, in N;

SDR is the standard dimension ratio;

d_e is the outside diameter of the pipe, in mm;

σ is the maximum tensile stress, in MPa;

SF is the safety factor;

σ_y is the tensile stress at yield, in MPa.

NOTE 1 A value of 2,0 is normally used for *SF*.

NOTE 2 The tensile stress at yield, $\sigma_{y,}$ is as provided by the pipe manufacturer.

The drag force, *F*, obtained by Formula (2), relates to an environmental temperature of 20 °C and can be applied to the pipe for a relatively short time. For higher temperatures, derating factors should be applied to Formula (2).

5.4.4 Valves

Valves shall be installed so that they do not expose the PE pipe to unnecessary stress during opening or closing. PE valves shall conform to ISO 4437-4.

Valves are available with either a steel/iron or a plastics body. With steel/iron-body valves, special precautions shall be taken against corrosion and to avoid stresses induced on the PE pipes by their weight.

5.4.5 Connection to working systems

Where there can be a release of gas in the working area, static-charge accumulation shall be avoided.

In order to avoid static charges, the pipeline system shall be connected to earth during manipulations, for example by draping water-soaked cloths, made of natural fibre, over all pipes and fittings likely to be handled so that the cloths touch both the pipe and the ground.

5.4.6 Backfilling

Unless otherwise specified, buried pipelines and casings shall have a minimum soil cover of 0,6 m (0,6 m cover can potentially not be necessary for small diameter PE service pipes). Exceptions may be made for pipes entering metering or regulating boxes, but such pipes shall be protected against external interference. Greater soil cover shall be provided in areas of deep ploughing, drainage, roads with heavy traffic, and railway or waterway crossings.

Excavated materials may be used as backfill provided that they are free from stones and sharp objects likely to damage the pipe and free of wooden materials. If this is not the case, qualified backfill material shall be used.

NOTE Backfill materials can be subject to national or local regulations.

Pipes made of PE100-RC show a higher resistance against slow crack growth, so may be installed without sand embedding and/or with the re-use of the excavated soil.

The pipe shall be uniformly supported; material around the pipe shall be compacted so as to avoid excessive pipe ovality. This shall be done layer by layer.

5.5 Pressure testing and commissioning

Pressure testing and commissioning shall be in accordance with EN 12327.

NOTE Pipeline pressures can be subject to national or local regulations.

Consideration shall be given to the need for any special precautions to be taken to protect persons and property if air or inert gas is used as the test medium.

For test temperatures below 0 °C, the possibility of a reduction in critical RCP pressure, p_{RCP}, shall be taken into account in the pipeline preparation and test procedure adopted.

Pressurized PE pipelines at ambient temperature are subject to expansion by creep that can potentially affect the results of pressure testing. At higher test pressures, this effect can be significant. Appropriate allowance shall be made for pressure losses due to creep when interpreting pressure test results.

If air is used, oil from the compressor shall be prevented from entering the pipeline and the air temperature shall not exceed 40 °C, to prevent damage to the pipes and/or fittings.

After the finalization of the piping installation, including the positive result of pressure testing, the piping system is prepared for commissioning.

6 Quality control

6.1 General

The pipes, fittings and associated equipment shall be inspected to confirm the conformity with the laying procedure.

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

Destructive and/or non-destructive testing[14][15]on joints made in the field may also be carried out to ensure that the quality conforms to the jointing procedure.

6.2 Inspection prior to laying

Pipes, fittings and associated equipment shall be inspected prior to laying to confirm conformity with the required ISO standard, pipe and fitting diameters, SDR and MRS as given by the pipe and fitting marking information.

Pipes and fittings showing obvious defects, e.g. excessive scoring, shall be clearly marked as unsuitable and discarded. Limitations on outside storage of pipes or fittings shall not have been exceeded.

The equipment used shall be in accordance with the relevant standards e.g. in case of equipment for fusion jointing ISO 12176-1 and ISO 12176-2. When standards do not exist, the equipment shall be as defined in industry specification and its use shall be in accordance with the manufacturer's instruction of use and maintenance.

Prior to use, the equipment shall be visually inspected to ensure that the device is free of damage, e.g. broken cables, and it shall be verified that calibration and maintenance frequencies, as specified by the manufacturer, are fulfilled.

A written jointing procedure shall be available.

6.3 Inspection during laying

6.3.1 Laying

Soil and trench conditions shall conform to the written installation procedure authorized by the pipeline operator.

If surface defects with a depth of more than 10 % of the nominal pipe wall thickness are found, the section concerned shall be cut out.

Inspection during the laying of pipelines and the construction of associated installations shall include the following:

a) inspection of the pipes for serious surface defects, deformation or pipe end toe-in, immediately prior to and during laying;

b) inspection of the trench to ensure that it is the correct depth and width and that it provides the minimum clearance with respect to other buried structures;

c) inspection of the bottom of the trench immediately prior to lowering the pipeline into place and during backfilling of the trench to ensure that the pipeline is not damaged by sharp objects, such as stones or pieces of metal;

d) inspection during the lowering of the pipeline into the trench to ensure that this takes place correctly, that no damage occurs and that the pipeline is placed in the correct position.

The installation of new PE materials (e.g. PE100-RC) can present a reason for pipeline operators to reconsider some of the above inspections (e.g. backfilling material requirements, etc).

6.3.2 Joint integrity

6.3.2.1 General

The quality of the joint depends on strict adherence to the written jointing procedure, the use of well-maintained/calibrated equipment conforming to the relevant standard and the competence of the operators.

Quality control shall be performed on-site by the persons involved in the work concerned. Further, supervision and inspection may be carried out by a supervisor who shall guarantee the quality of the work performed and in addition provide a quality control report.

6.3.2.2 Visual inspection criteria

6.3.2.2.1 Butt fusion joints

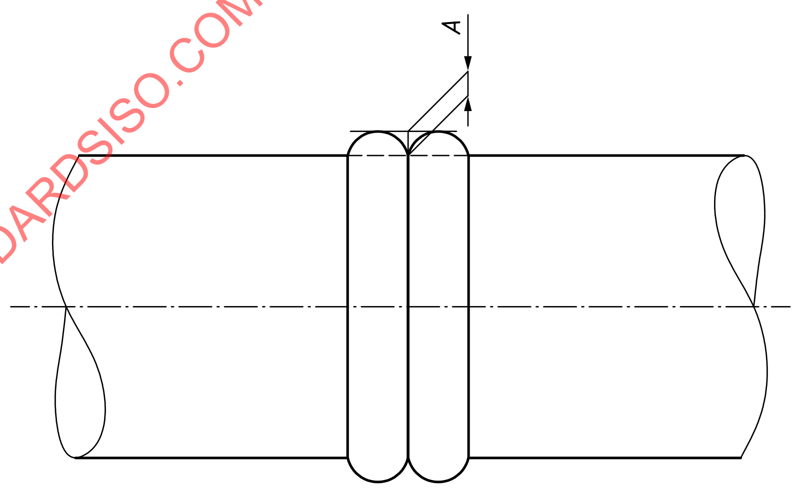
The following inspections shall be executed:

a) **Bead symmetry**

Joints shall have a smooth symmetrical bead around the entire pipe circumference as shown in Figure 2. The depth, *A*, of the bead depression shall not extend below the pipe surface.

An asymmetrical bead profile between the same components shall initially be considered as indicative of poor joint quality subject to a confirmation assessment by an authorized person.

Where the pipes and/or fittings have different MFRs, the bead may be asymmetrical but still satisfactory. In assessing the results of the joint tests under standard conditions, acceptable levels of asymmetry shall be determined.



Key

A depth

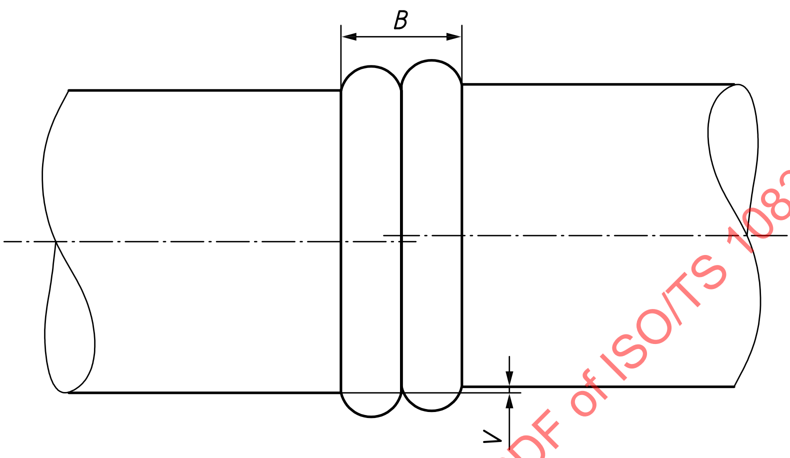
Figure 2 — Bead symmetry

b) **Alignment**

Pipes, fittings and valves shall be as closely aligned as possible.

The misalignment *V* shall not exceed 0,1 e_n. Where this leads to values of less than 1 mm, testing of joints shall be undertaken to identify the maximum allowable misalignment (Figure 3).

This value shall not be exceeded anywhere around the circumference of the two parts adjacent to the fusion bead.



Key

V misalignment

B bead width

Figure 3 — Alignment

One method of determining an acceptable bead width value, *B*, is by experimentally using pipes and a butt fusion machine operating at the specified conditions. The mean value, B_m, is determined from several joints made under the conditions defined in the jointing procedure. It is recommended, for quality control purposes on-site, that the measured bead width *B* does not exceed ±20 % of B_m.

The use of GO/NO-GO gauges, manufactured according to these recommended limits, can potentially facilitate checking (Figure 5).

c) **Bead removal**

Removal of the external fusion bead, using appropriate tools, is possible without damage to the pipe (Figure 4). The removed bead is then available for inspection.

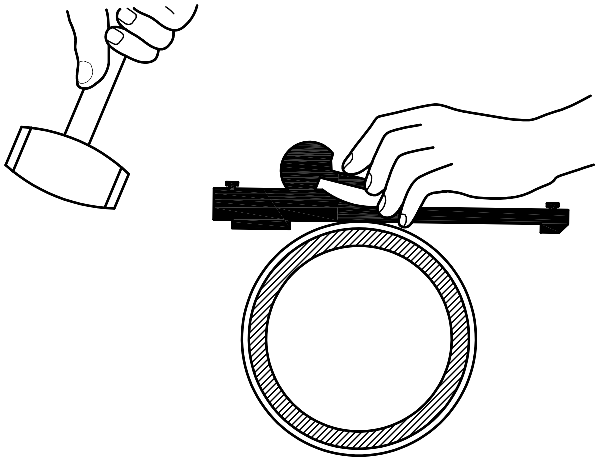


Figure 4 — Bead removal

Bead gauges may be used to assess the bead width (Figure 5). A visual examination of the underside of the bead may be undertaken. Evidence of contamination, holes, offset or damage by molten material shall be cause for rejection.

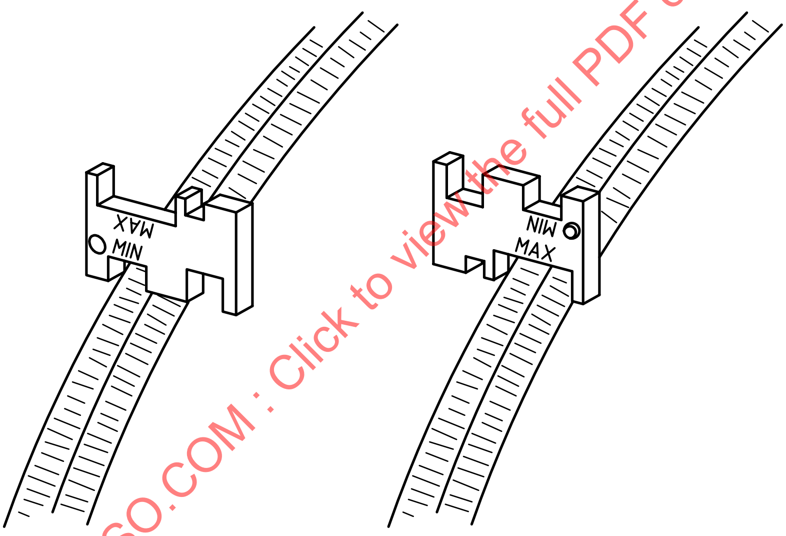
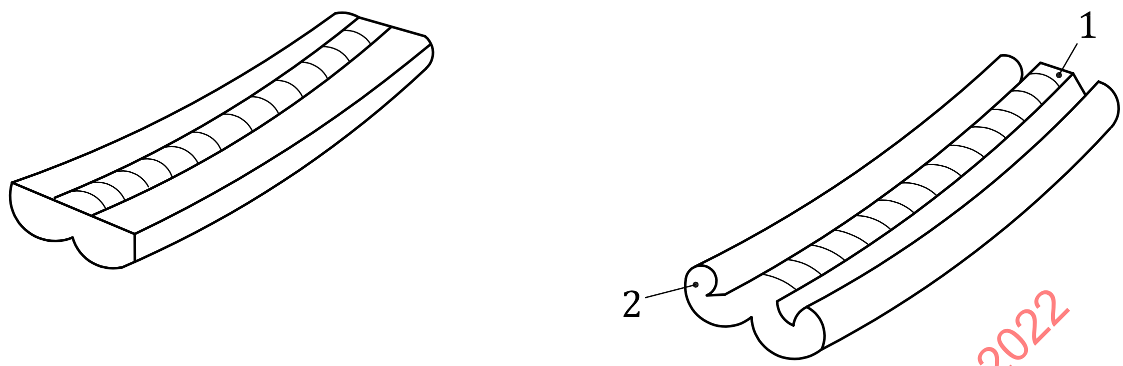


Figure 5 — Bead gauges

The bead shall be solid and rounded, with a broad root, as shown in Figure 6 a). Hollow beads with a thin root and curled appearance can potentially have been formed with excessive pressure or no heat soak and shall be rejected; see Figure 6 b).



a) Correct bead root **b) Rejected bead route**

Key

1 thin root

2 curling

Figure 6 — Bead root

When the bead has been removed, a bend-back test (Figure 7) can be made every few cm to examine for the presence of slit defects.

Slit defects are indicative of fine-dust contamination within the fusion interface, possibly arising from contact with a dirty heating plate, and the joint shall be rejected.

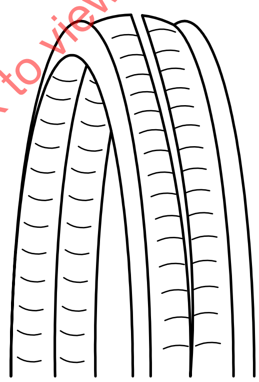


Figure 7 — Bend-back test

6.3.2.2.2 Electrofusion socket joints

The following inspections shall be executed:

a) **Pipe alignment**

A check shall be made that the pipes and fittings have been properly aligned in accordance with the written jointing procedure.

b) **Scraping**

A check shall be made that scraping in accordance with the written jointing procedure has been carried out over the entire circumference of the pipe (Figure 8).

There shall be clear evidence of scraping on either side of the socket. Particular attention shall be given to inspecting the underneath of the pipe.

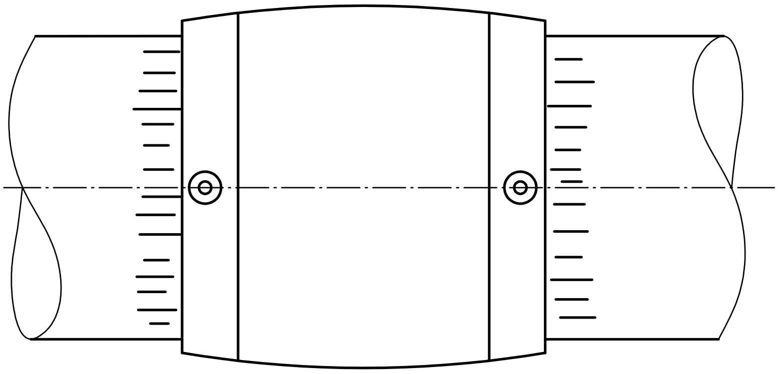
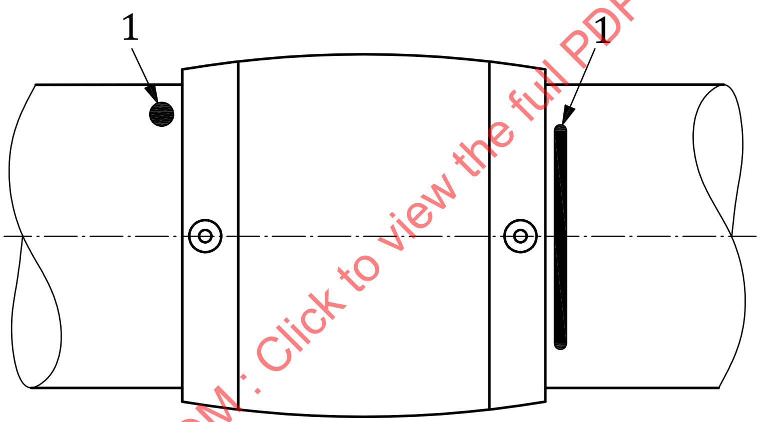


Figure 8 — Scraping

c) **Insertion**

Penetration markings shall be checked to confirm that complete insertion of the pipe or spigot ends has been achieved and maintained during the fusion process (Figure 9).



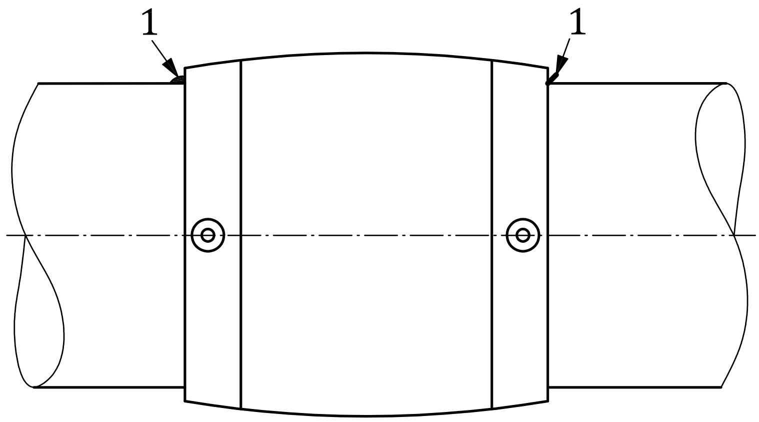
Key

1 insertion markings

Figure 9 — Penetration markings

d) **Molten material**

A check shall be made that molten material from the fusion process has not exuded out from inside the fitting (Figure 10).



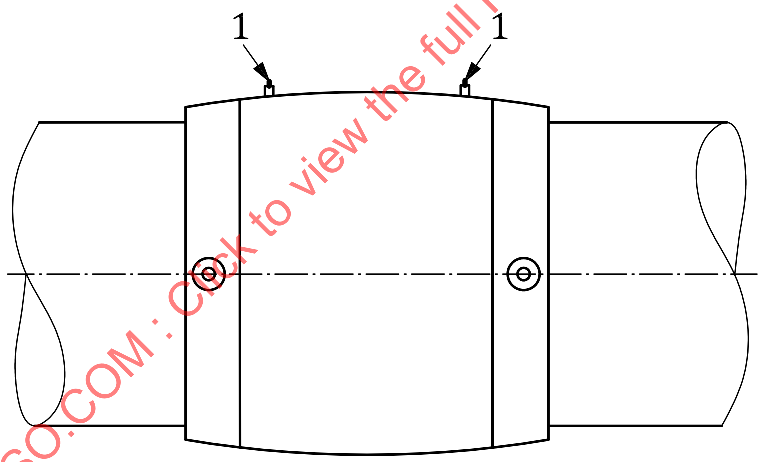
Key

1 exuded molten material

Figure 10 — Molten material

e) **Heating indicators**

If the fitting is designed with heating indicators, they should be in positions conforming to the manufacturer's instructions after jointing has been completed (Figure 11).



Key

1 activated heating indicators

Figure 11 — Heating indicators

f) **Cooling time**

The clamps shall be removed only once the cooling time (as indicated on the fittings, e.g. C.T.) has elapsed.

g) **Position of heating wires**

Following fusion jointing, the heating wires shall not show any displacement outside the fitting body influencing the fusion quality.

For larger electrofusion (EF) couplers, e.g. diameter ≥ 315 mm, the first winding can potentially become visible after the electrofusion. This has no negative effect on the fusion quality.

NOTE 1 The first winding of the heating coil is not part of the fusion zone.

h) **Jointing energy**

The completed electrofusion joint fusion energy should be checked to be within acceptable limits.

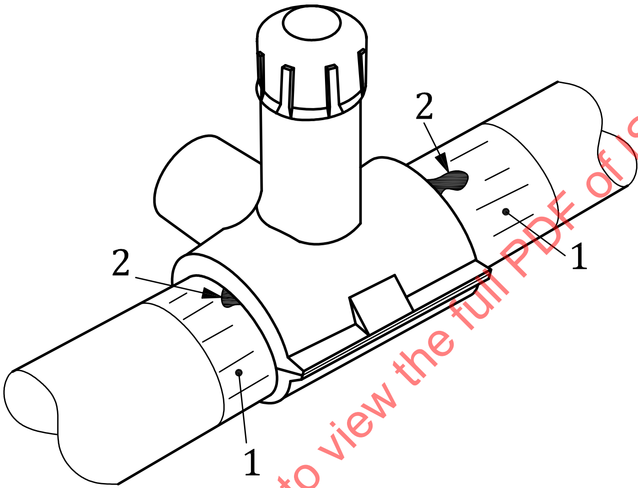
NOTE 2 Automatic fusion control units conforming to ISO 12176-2 record electrical output parameters, the duration of the fusion process and the environment temperature. These data are used for the purpose of this clause.

6.3.2.2.3 Saddles and tapping tees

The following inspections shall be executed:

a) **Scraping**

A check shall be made that scraping has been carried out in accordance with the written jointing procedure over the entire fusion area (Figure 12).



Key

1 scraping

2 exuded molten material

Figure 12 — Checking saddles and tapping tees

b) **Further visual checks**

The pipe wall shall show no signs of collapse.

A check shall be made that molten material from the fusion process or heating wires have not exuded out from inside the fitting (Figure 12).

c) **Heating indicators**

If the saddle or tapping tee is designed with heating indicators, they shall be in positions conforming to the manufacturer's instructions after jointing has been completed.

d) **Cooling time**

When a special clamp is required for saddles or tapping tees, it shall not be removed and the joint shall not be disturbed before the specified cooling time has elapsed. Before the tapping of the pipe, further cooling time can be required as specified by the fitting manufacturer.

e) **Ancillary tooling**

The use of ancillary tooling, such as pipe clamps, shall not result in significant damage to pipe surfaces adjacent to the joint.

f) **Jointing energy**

The completed EF joint fusion energy should be checked to be within acceptable limits.

NOTE Automatic fusion control units conforming to ISO 12176-2 record electrical output parameters, the duration of the fusion process and the environment temperature. These data are used for the purpose of this clause.

Annex A
(normative)

Butt fusion jointing procedure

A.1 General

Butt fusion joints shall be made under defined conditions of pressure, time and temperature, using a written procedure (5.3). Mating surfaces are heated to their fusion temperature and then brought into contact with one another. The following clauses provide basic information relating to a general butt fusion procedure.

ISO 21307 provides specifications for jointing. Other industrial butt fusion jointing procedures may be used provided that they are suitable for the piping system.

A.2 Climate conditions

The fusion operation may be carried out at a different ambient temperature provided the variations are within the limits specified in the jointing procedure.

Extreme ambient temperatures, rainfall and wind can adversely affect the fusion process. For cold weather and wind, special precautions such as shielding, end caps and longer heating times shall be taken. For high ambient temperatures and situations with significant solar heating of the pipe surface, special precautions such as shielding and extended cooling time shall be taken.

A.3 Fusion temperature

The production of a strong fusion joint depends, among other things, upon the fusion temperature of the PE material: overheating can degrade the material, and insufficient heating will not soften it adequately.

The fusion temperature range over which any particular PE material can be satisfactorily jointed shall be considered. The jointing procedure shall specify the heating cycle and the temperature levels for the polyethylene material chosen.

A.4 Fusion equipment

The butt fusion equipment used shall conform to ISO 12176-1. As high-quality fusion joints cannot be made with fusion equipment in poor condition, maintenance and calibration of the fusion equipment is very important and shall be carried out on a regular basis. The cleanliness and integrity of the heating surfaces, the ability of the heating tools to produce the correct temperature, and the correct alignment and operation of the equipment are of paramount importance.

The heater plates are designed to maintain uniform temperatures within the fusion temperature range and shall have a means of measuring and indicating the temperature. A precise temperature measurement device such as a pyrometer or a digital thermometer with a surface temperature sensor may be used to check the surface temperature of the heating tools, although additional care is necessary to avoid inconsistency of readings when such a device is used.

All heating tools used shall be electrically heated. It is preferable to use fully-automated butt fusion equipment with retrievable jointing records.

Power generators and butt fusion machines shall be designed according to the generally accepted safety requirements.

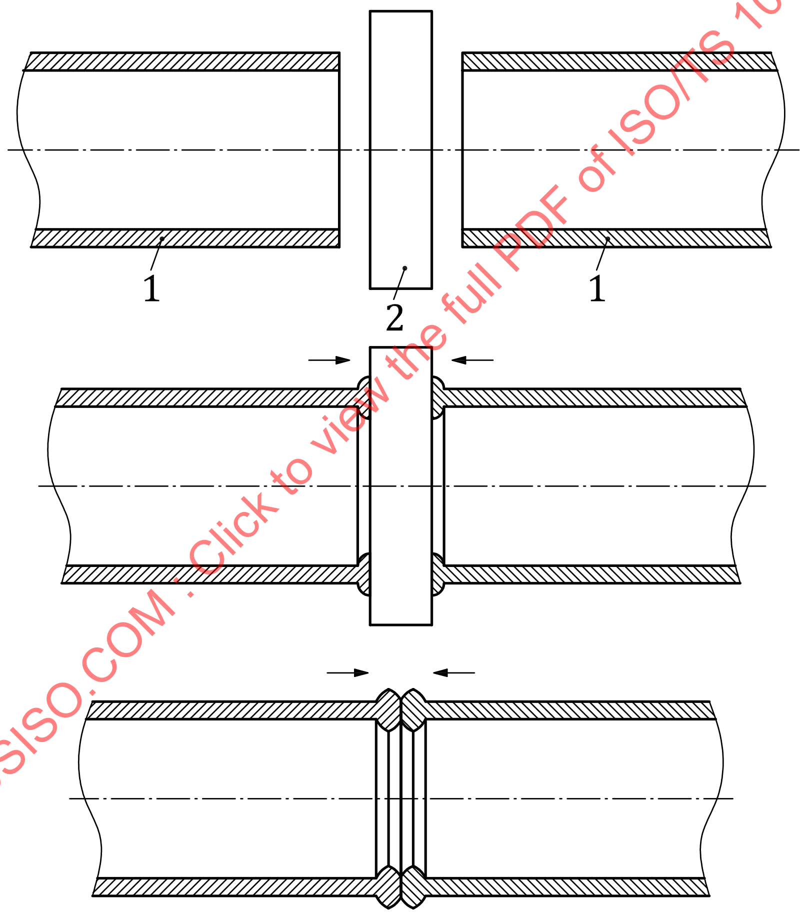
NOTE Electrical safety can depend on local regulations.

The butt fusion machine pressure shall be kept steady during the relevant phases of the fusion process.

A.5 Butt fusion

A.5.1 Principle

The butt fusion technique consists of heating the planed ends of the mating surfaces by holding them against a flat heating plate until molten, removing the heating plate, pushing the two softened ends against one another, holding under pressure for a prescribed time and allowing the joint to cool (Figure A.1)



Key

1 pipe/fitting ends

2 heater plate

Figure A.1 — Butt fusion

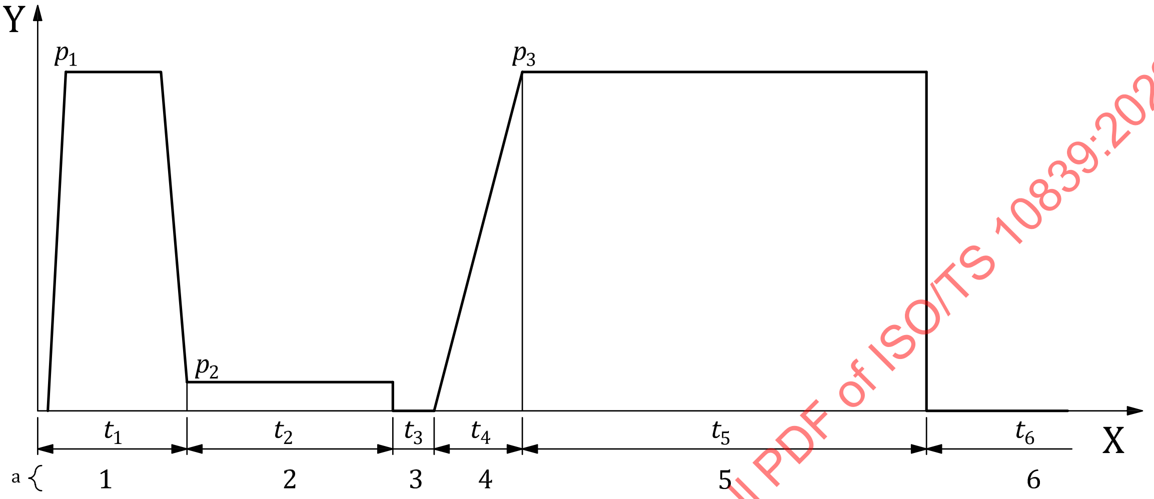
Butt fusion is not recommended for pipes ≤ 63 mm in diameter. Pipes and/or fittings with fusion ends of different SDR values shall not be joined by butt fusion.

A.5.2 Butt fusion cycle

The butt fusion cycle can be represented by a pressure/time diagram for a defined fusion temperature. Different butt fusion cycles are available, depending on the PE material used, the pipe diameter, wall thickness and the working conditions.

The butt fusion cycle to be used shall be specified in the written procedure.

An example of a butt fusion diagram is given in Figure A.2.



Key

X time, t

Y pressure, p

p_1 bead-up pressure

p_2 heat soak pressure

p_3 fusion jointing pressure

a Phase.

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 A.2 — Single low-pressure fusion jointing cycle

The pressures shall be chosen so that the required force is produced at the interface, irrespective of frictional and pressure losses in the butt fusion machine and drag resistance from the pipe system.

In the case of machines with fluid power rams, the force may be indicated in terms of the applied cylinder pressure. For such machines, a specific calibration table shall be provided that gives the relationship between the real interface force and the pressure indicated by the pressure gauge.

A.5.3 Butt fusion temperature

The butt fusion temperature is normally situated between 210 °C and 230 °C and is given in the jointing procedure, e.g. ISO 21307.

A.5.4 Butt fusion jointing

The following list gives an overview of the minimum operations necessary to produce a butt fusion joint with a specified butt fusion cycle and temperature and a powered ram butt fusion machine.

— Check that the butt fusion machine is compatible with the pipe diameter and wall thickness and the prescribed butt fusion cycle.

— Reduce the drag resistance as much as possible, e.g. by using pipe rollers.

— Firmly clamp the spigot ends of the pipe(s) and/or the spigot ends of the fitting(s) in the butt fusion machine.

— Clean the spigot ends.

— Plane the spigot ends parallel by moving the movable clamp against the planing tool (Figure A.3). The closing pressure shall be sufficient to produce a steady flow of PE shavings on both sides of the planing tool. Planing is complete when the spigot ends are planed and parallel to each other over the entire spigot circumferences.

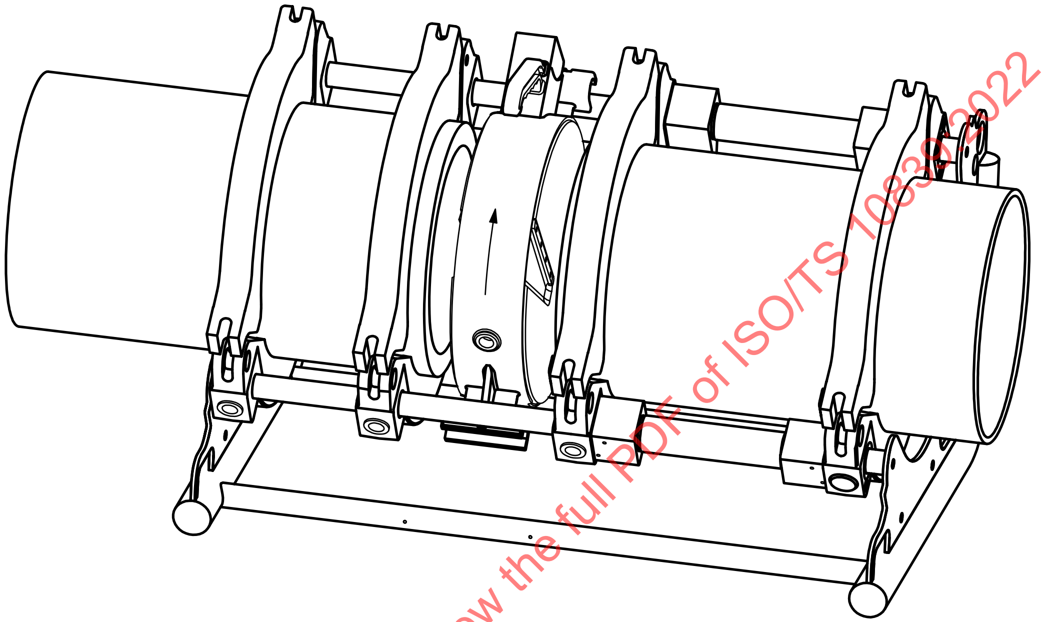


Figure A.3 — Planning the spigot ends

— Lower the pressure, keeping the planing tool rotating in order to avoid a burr on the pipe and/or fitting faces. Move the movable clamp backwards and remove the planing tool.

— 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 (if the shape is out-of-round) and aligned to ensure conformance to relevant codes of practice or industry guidelines.

— Gauge the pressure caused both by the frictional losses in the butt fusion machine and the drag resistance, by moving the clamp forwards, and add this pressure to the required fusion pressure (Figure A.2, p_3).

— Ensure that the fusion surfaces are not contaminated before starting with the bead-up process.

— The heater plate shall be clean. Polyethylene residues shall only be removed from the heater plate with a wooden spatula.

— Check that the surface coating of the heater plate is intact and without scratches.

— Check that the heater plate is at the correct fusion temperature.

— 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 (Figure A.4). Apply the fusion pressure, including the measured additional pressure, until the minimum specified bead-up width has been reached.

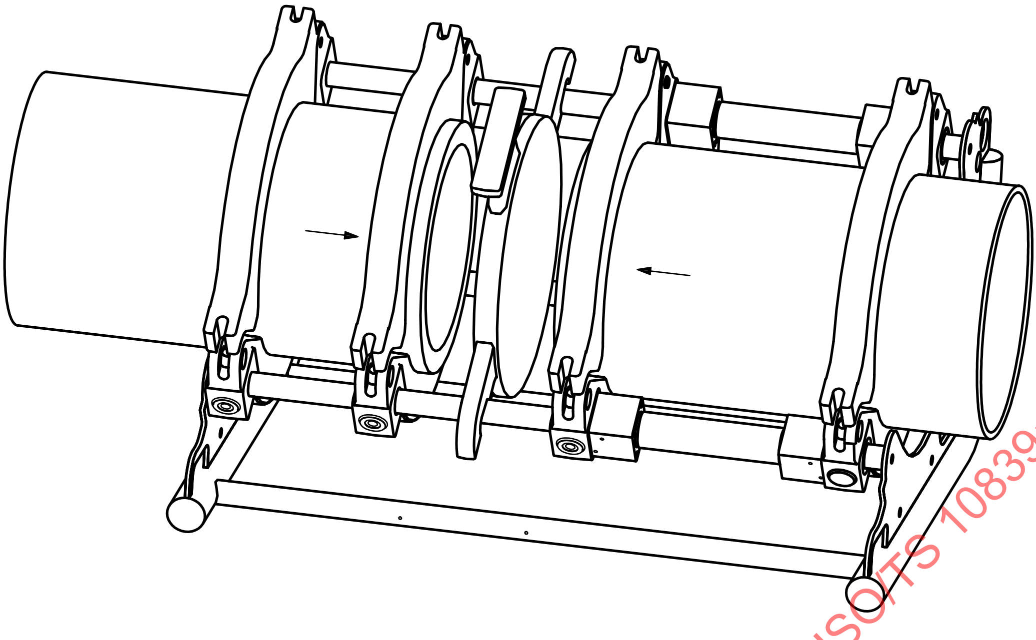


Figure A.4 — Heating the spigot ends

— Reduce the pressure to a level at which contact is just maintained between the spigot ends and the heater plate.

— When the heat soak time has elapsed, open the butt fusion machine and remove the heater plate. Check the heated spigot ends quickly for possible damage to the melted ends caused by the removal of the heater plate, and close the butt fusion machine again. The period between opening and closing shall be within the maximum time given in the jointing procedure.

— Store the heater plate in a protective enclosure when not in use.

— The butt fusion machine shall remain closed and the joint under pressure during the cooling time in the machine under pressure (t_5). It is important that the cooling period is respected.

— When the cooling times in the machine has elapsed, release the pressure in the butt fusion machine.

— When removed, the assembly shall be handled with care.

Annex B
(normative)

Electrofusion jointing

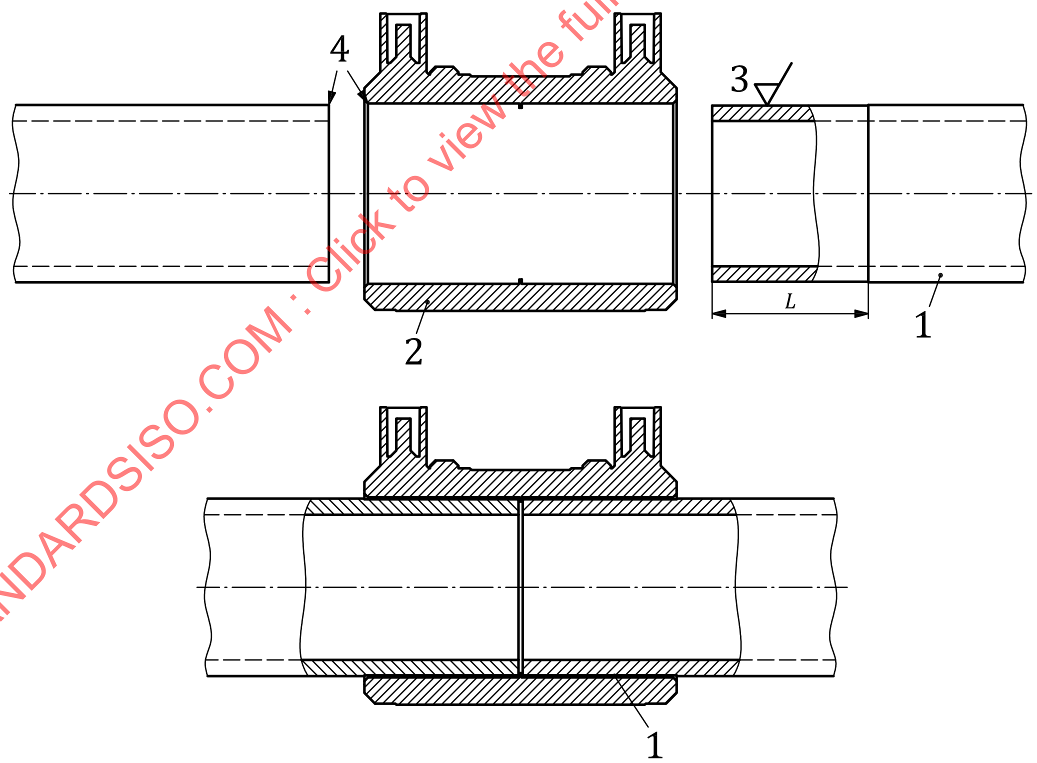
B.1 General

Electrofusion fittings may include sockets, for example couplers, reducers, tees, end caps, elbows, and saddles, such as tapping tees and branches. The basic principle of joining such fittings by electrofusion consists of heating, using the Joule effect, an electrical coil incorporated in the internal surfaces (fusion surfaces) of the fitting, causing the material adjacent to the coil to melt and making the pipe and fitting surfaces fuse (Figure B1).

Electrofusion fittings can be used to join piping components, e.g. pipes, branches or spigot fittings.

Electrofusion fittings and piping components shall be made from polyethylene designated according to ISO 4437-1 (e.g. PE80 or PE100) and different SDR(s) ranges.

Care shall be taken to use only electrofusion fittings with a design MOP and SDR range compatible with the PE pipes and spigot fittings to be joined.



Key

1 pipe/fitting surface - joined area
2 fitting's body
3 pipe/fitting scraped surface
4 diameter
L insertion depth

Figure B.1 — Basic principle of electrofusion jointing process

B.2 Climate conditions

The fusion operation may be carried out without any special precautions for variations in ambient temperature, provided these variations are within the limits specified in the jointing procedure. If some adjustment in the electrical power supplied to the fitting is necessary to cater for extreme ambient temperatures, the jointing procedure shall specify suitable electrofusion equipment. Cold weather, rainfall and wind can adversely affect the fusion process. Under these circumstances, special precautions based on the electrofusion fittings manufacturers instruction shall be considered.

B.3 Electrofusion equipment

B.3.1 General

Maintenance and calibration of the control units and generator is very important and shall be carried out on a regular basis to achieve high-quality fusion joints. Also, other electrofusion equipment, e.g. scraper tools, power cables, etc. require a check for correct function and maintenance.

Power generators and control units shall be designed according to the generally accepted safety requirements.

NOTE Electrical safety can depend on local regulations.

B.3.2 Control unit

The control unit shall conform to ISO 12176-2. It is preferable to use automated electrofusion equipment with retrievable jointing records and able to decode data from ISO 12176-3, ISO 12176-4 and ISO 12176-5.

The jointing procedure shall specify the type of fusion equipment to be used.

The electrofusion control unit is designed to provide the correct fusion energy to electrofusion fittings. This energy input is based on the parameters set by the fitting manufacturers (e.g. voltage, fusion time, temperature). Parameters can be given in different ways, e.g. barcode or two-dimensional coding.

The electrical supply to the control unit can be either supplied by mains or power generators or others.

The electrofusion control unit output cable connectors shall be compatible with the fitting electrical terminals. Use appropriate terminal adaptors if necessary.

B.3.3 Power generator

If a power generator is used it shall be able to deliver the power required by the fitting. Information on the required power can be found in technical documentation released either by fitting or control unit manufacturers.

B.4 Electrofusion

B.4.1 Preparation

The following general procedure gives an overview of the minimum operations necessary to prepare for electrofusion jointing. More specific instruction, if any, can be given by the electrofusion fitting manufacturer. Other procedures can be found in Reference [18].

B.4.2 General

Electrofusion fittings shall be kept in their protective packaging until they are ready to be joined to a pipe or spigot fitting. The surfaces to be fused shall be dry and clean before beginning the jointing procedure.

