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Classification and information on design and applications of plastics piping systems used for renovation and replacement

Classification et informations relatives à la conception et aux applications des systèmes de canalisations en plastique destinés à la rénovation et au remplacement

Reference number
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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 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 ISO/TC 138 *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 8, *Rehabilitation of pipeline systems*.

This second edition cancels and replaces the first edition (ISO 11295:2010), which has been technically revised.

This edition includes the following significant changes with respect to the previous edition:

— Clauses 3, 4, 5 and 6 have been technically revised;

— Clause 7 for the classification of replacement techniques has been added.

Introduction

This document classifies the techniques used for the renovation and trenchless replacement of existing pipelines and gives information on the design and application of plastics piping systems used for such rehabilitation.

In recent years, the rehabilitation of pipeline systems has become increasingly important and will continue to be so.

Pipeline systems are continuously required to satisfy physical, chemical, biochemical and biological demands. These demands depend on planning, material, construction, type and period of use.

When pipeline systems become operational, proper system management has to be put in place. In addition to inspection and cleaning, rehabilitation of the pipeline can be required. Rehabilitation is carried out when there is a need to restore or upgrade the performance of a pipeline system. Rehabilitation can consist of repair, renovation or replacement.

To coincide with the publication of ISO rehabilitation product standards for various application areas using methods other than renovation, the need to extend the scope of this document to include families of trenchless replacement techniques was recognized.

Classification and information on design and applications of plastics piping systems used for renovation and replacement

1 Scope

This document defines and describes families of techniques for the renovation and trenchless replacement (on or off the line of an existing pipeline) of non-pressure and pressure pipelines through the use of plastics pipes, including plastics composites formed *in situ* into pipes, fittings and ancillary components. It does not include new construction provided as network extension. For each technique family, it identifies areas of application including, but not limited to, underground drainage and sewerage, and underground water and gas supply networks.

This document provides information on the principles of, but not the detailed methodologies for, the design of plastics piping systems used for renovation or trenchless replacement of existing pipelines, covering:

— existing pipeline and site conditions;

— functions of the new pipeline;

— structural performance;

— hydraulic performance;

— installation aspects and site impact;

— other factors affecting renovation or trenchless replacement technique selection.

Necessary work on the existing pipeline prior to renovation and/or trenchless replacement is outside the scope of this document.

This document provides information needed to determine viable options and for identification of the optimal technique with regard to a given set of rehabilitation objectives.

NOTE It is the responsibility of the designer to choose and design the renovation or trenchless replacement system.

It does not specify the calculation methods to determine, for each viable technique, the required amount of lining or replacement pipe material needed to secure the desired performance of the rehabilitated pipeline.

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 1043-1, *Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1043-1 and the following 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 General

3.1.1
rehabilitation
measures for restoring or upgrading the performance of existing pipeline systems, including *renovation* (3.1.2), *repair* (3.1.3) and *replacement* (3.1.4)

3.1.2
renovation
work incorporating all or part of the original fabric of the pipeline, by means of which its current performance is improved

3.1.3
repair
rectification of local damage

3.1.4
replacement
construction of a new pipeline, on or off the line of an existing pipeline, where the function of the new pipeline system incorporates that of the old

3.1.5
network extension
new construction off the line of a pipeline or a network with the aim to expand the total capacity of the network

3.1.6
trenchless replacement
replacement (3.1.4) without opening trenches other than small excavations to provide access for the particular technique

3.1.7
maintenance
routine work undertaken to ensure the continuing performance of an asset

3.1.8
independent pressure pipe liner
liner (3.2.3) capable on its own of resisting without failure all applicable internal loads throughout its design life

3.1.9
interactive pressure pipe liner
liner (3.2.3) which relies on the existing pipeline for radial support in order to resist without failure all applicable internal loads throughout its design life

3.1.10
fully structural renovation
use of an *independent pressure pipe liner* (3.1.8) which is capable of resisting all external loads irrespective of the condition of the existing pipeline

3.1.11
semi-structural renovation
use of an *interactive pressure pipe liner* (3.1.9) which is capable of long-term hole and gap spanning at operational pressure

3.1.12
flow diversion
temporary isolation of the section of pipeline to be rehabilitated by the use of a temporary bypass or other means

3.2 Techniques

3.2.1
technique family
grouping of *renovation* (3.1.2) or *trenchless replacement* (3.1.6) techniques which are considered to have common characteristics for standardization purposes

3.2.2
lining pipe
pipe inserted for *renovation* (3.1.2) purposes

3.2.3
liner
lining pipe (3.2.2) after installation

3.2.4
lining system
lining pipe (3.2.2) and all relevant fittings inserted into an existing pipeline for the purposes of *renovation* (3.1.2)

3.2.5
lining with continuous pipes
lining with pipe made continuous prior to insertion, where the diameter of the *lining pipe* (3.2.2) remains unchanged

3.2.6
lining with close-fit pipes
lining with a continuous pipe (3.2.5) for which the cross-section is reduced to facilitate installation and reverted after installation to provide a close fit to the existing pipe

3.2.7
lining with cured-in-place pipes
lining with a flexible tube impregnated with a thermosetting resin, which produces a pipe after resin cure

3.2.8
lining with discrete pipes
lining with short lengths of pipe which are jointed to form a continuous pipe one by one during insertion

3.2.9
lining with adhesive-backed hoses
lining with a reinforced hose which relies on an adhesive bond to the host pipe to provide resistance to collapse

3.2.10
lining with spirally-wound pipes
lining with a profiled strip, spirally wound to form a continuous pipe after installation

3.2.11
lining with sprayed polymeric materials
lining with a sprayed two-part polymeric resin material that forms a continuous pipe after resin cure

3.2.12
lining with inserted hoses
lining with a reinforced hose which is either permanently shaped or re-rounded after installation by the application of an internal pressure

3.2.13
lining with a rigidly anchored plastics inner layer
lining with a single rigid annulus of structural cementitious grout formed between a plastics layer and the host pipe, where the plastics layer is permanently anchored in the grout

3.2.14
lining with pipe segments
lining with prefabricated segments bonded to the existing pipe, which either have longitudinal joints and cover the whole of the pipe circumference, or cover only part of circumference

3.2.15
pipe bursting
on-the-line *replacement* (3.1.4) method in which an existing pipe is broken by longitudinal splitting or brittle fracture, using a mechanically applied force from within, where the pipe fragments are forced into the surrounding ground and a new pipe of the same, smaller or larger diameter, is simultaneously pulled in

3.2.16
pipe removal
on-the-line *replacement* (3.1.4) method, in which the existing pipe is removed by *pipe eating* (3.2.17) or *pipe extraction* (3.2.18) and a new pipe is installed

3.2.17
pipe eating
type of *pipe removal* (3.2.16), where the existing pipe is progressively broken up and removed along with an annulus of the ground immediately surrounding the existing pipe

3.2.18
pipe extraction
type of *pipe removal* (3.2.16), where the existing pipe is extracted by pulling or pushing and replaced with a new one, either simultaneously or as a separate step

3.2.19
horizontal directional drilling
off-the-line *replacement* (3.1.4) method in which a pilot bore is drilled using a steerable drilling head connected to flexible rods and then the bore is enlarged by reamers up to the diameter required for the pipe or pipes subsequently pulled/pushed into place

3.2.20
impact moling
off-the-line *replacement* (3.1.4) method in which pipes are pulled in behind a pneumatic powered soil displacement hammer

3.2.21
pipe jacking
off-the-line *replacement* (3.1.4) method in which pipes are pushed through the ground, and the soil inside removed either manually, mechanically or using a slurry system

3.2.22
auger boring
type of *pipe jacking* (3.2.21), where the bore is excavated by a rotating cutting head attached to an auger which continuously removes the spoil, and the pipeline is pushed independently from the auger

3.2.23
microtunnelling
type of *pipe jacking* (3.2.21) where pipes are pushed behind a steerable, small scale tunnelling machine, remotely controlled from the surface

3.2.24
grout system
cement-based grout including any fillers, reinforcement or other additives or admixtures, in specified proportions

3.3 Service conditions

3.3.1
nominal pressure
PN
numerical designation used for reference purposes related to the mechanical characteristics of the component of a piping system

Note 1 to entry: For plastics piping systems conveying water, it corresponds to the maximum continuous operating pressure, expressed in bar (1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2), which can be sustained with water at 20 °C, based on the minimum design coefficient.

3.3.2
internal pressure resistance
ability to withstand internal hydrostatic pressurization

3.3.3
allowable operating pressure
PFA
maximum hydrostatic pressure that a component is capable of withstanding continuously in service

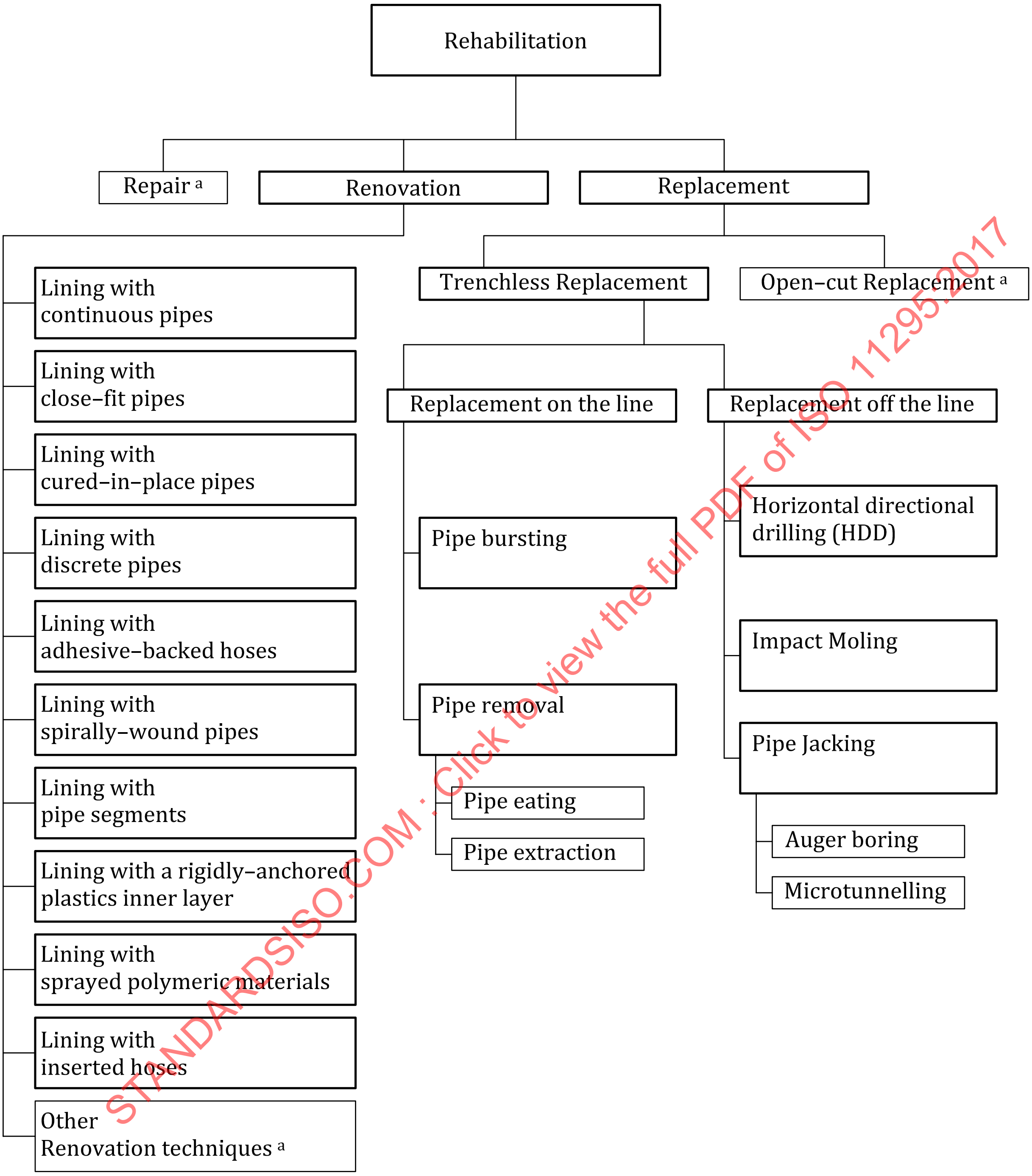
4 Abbreviated terms

For the purposes of this document, the abbreviated terms given in ISO 1043-1 and the following apply.

CCTV	closed circuit television
HDD	horizontal directional drilling
EP	epoxy resin
GRP	glass-reinforced thermosetting plastics
PE	polyethylene
PP	polypropylene
PRC	polyester resin concrete
PUR	polyurethane
PVC-U	unplasticized poly(vinyl chloride)
UP	unsaturated polyester resin
VE	vinyl ester resin

5 Classification of renovation and replacement techniques

Renovation and replacement techniques within the scope of this document are classified in Figure 1.



a Outside the scope of this document.

Figure 1 — Renovation and trenchless replacement technique families using plastics pipes defined in the overall context of rehabilitation of pipeline systems

6 Classification of renovation techniques

6.1 General

Renovation technique families using plastics pipes are classified in accordance with Figure 1.

Techniques used for the renovation of continuous lengths of existing pipeline usually between two or more access points shall be classified in accordance with 6.2 to 6.11, where the different renovation technique families are defined and their respective features including materials, application, as well as geometric performance and installation characteristics are described.

NOTE 1 The pipe materials listed in 6.2 to 6.11 reflect the state-of-the-art in the technique families on the date of publication of this document. Not all technique families/material-combinations are covered by a product standard. The Bibliography gives relevant available documents.

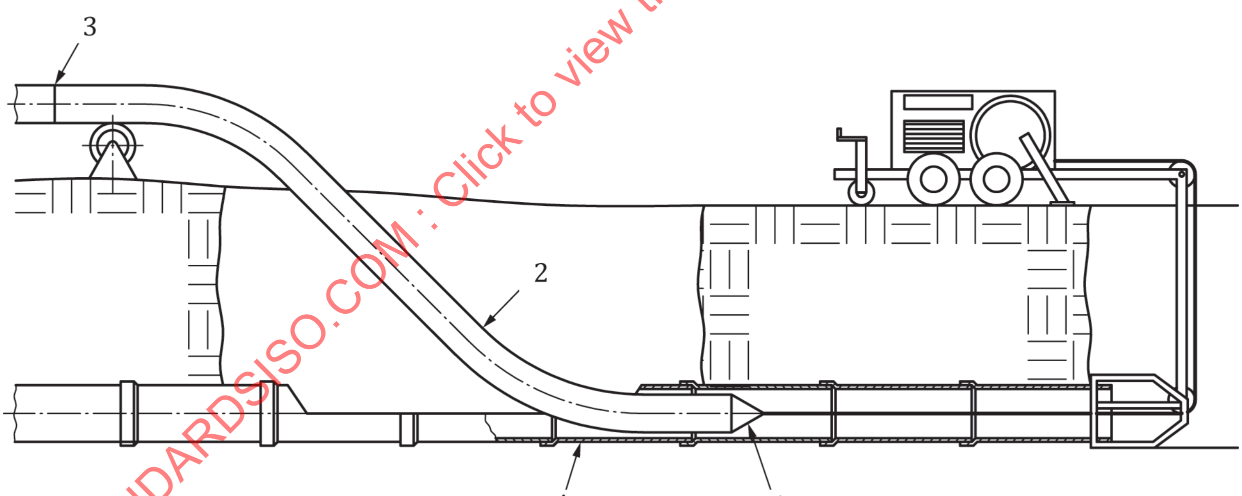
NOTE 2 The application areas covered by existing product standards include underground drainage and sewerage and underground water and gas supply networks.

NOTE 3 The maximum and minimum sizes and lengths listed for technique families are those typical at the time of publication of this document.

6.2 Lining with continuous pipes

Lining is carried out with pipes made continuous prior to insertion, where the diameter of the lining pipe remains unchanged (see Figure 2 and Table 1).

NOTE This is often referred to as slip-lining.



Key

1 pulling head

2 lining pipe

3 prior jointing of lining pipe

4 existing pipe

Figure 2 — Lining with continuous pipes

Table 1 — Features of lining with continuous pipes

Feature	Description
Relevant documents:	ISO 11296-2, ISO 11297-2, ISO 11298-2, ISO 11299-2
Materials:	PE
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— minimum size: 100 mm; — maximum size: 1 200 mm; — maximum length: 750 m; — capable of accommodating slightly curved alignments of the existing pipe.
Performance:	— significant reduction in hydraulic (volumetric and flow) capacity; — invert grade of liner can deviate from that of existing pipeline; — structural rehabilitation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.
Installation characteristics:	a) pipes manufactured or prior assembled into the continuous length required; b) insertion possible by pushing and/or pulling; c) surface working space: storage of the whole insertion length required on surface: 1) small diameters (typically ≤180 mm) can be supplied on coils, small space; 2) larger diameters: supplied in straight lengths; d) access to the existing pipeline: generally requires local excavation; e) technique does not rely on adhesion to host pipe; f) flow diversion is typically required for installation; g) the annular space can be grouted, e.g. in non-pressure applications, to fix line and level and/or prevent subsequent movement; h) live insertion is possible (but excl. drinking water applications for hygiene reasons); i) reconnection of laterals: generally requires excavation.
Installation equipment:	— rollers to support the entire length of the lining pipe string (except where pipe is inserted directly from a coil); — pushing unit, if applicable; — rollers to guide the lining pipe into the existing pipeline; — winch or rod puller to pull the lining pipe through the existing pipeline; — jointing equipment appropriate to the material; — grouting equipment, if applicable.
Surface area:	— for the lining pipe string (or coil trailer for smaller diameters) at the insertion end; — for a winch or a rod puller at the receiving end.
Excavation:	— at the insertion end: — long enough to allow the lining pipe to enter the existing pipeline, taking account of the permissible minimum bending radius; — wide enough for the guidance equipment and pushing equipment if applicable; — at the receiving end: — large enough to accommodate the lining pipe nose cone and the winch mast or rod puller, where applicable.

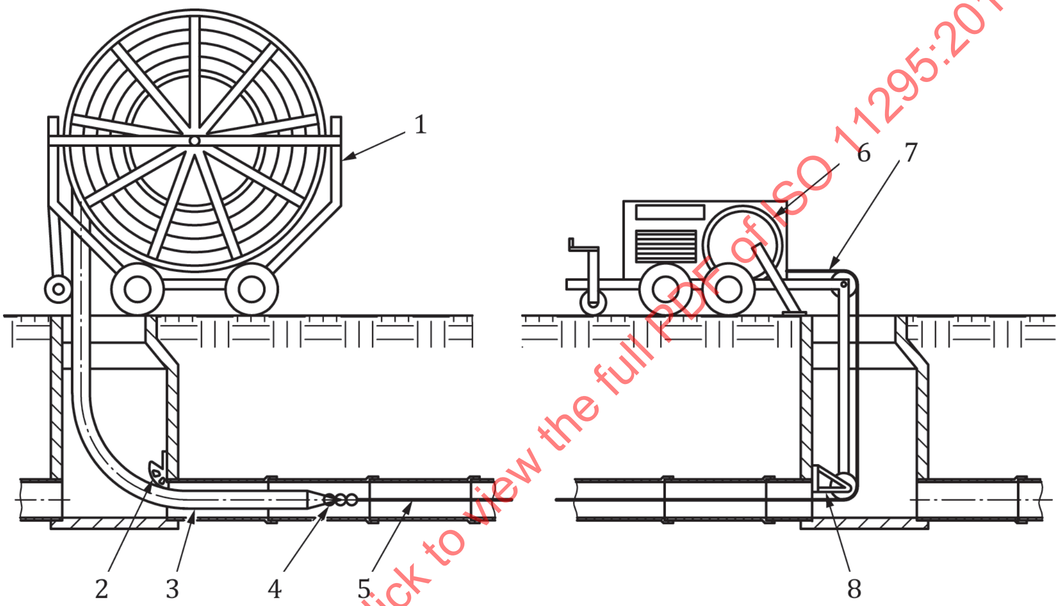
6.3 Lining with close-fit pipes

Lining is carried out with a continuous pipe for which the external dimension is reduced to facilitate installation and reverted after installation to provide a close fit to the existing pipe.

Methods of lining with close-fit pipes are shown in Figure 3 (Method A), Figure 4 (Method B) and Table 2.

a) Method A: reduction in the pipe manufacturing plant — the pipe is supplied coiled on a reel from which it is directly inserted.

b) Method B: reduction on site — the pipe is fed through diameter reduction or folding equipment and inserted.

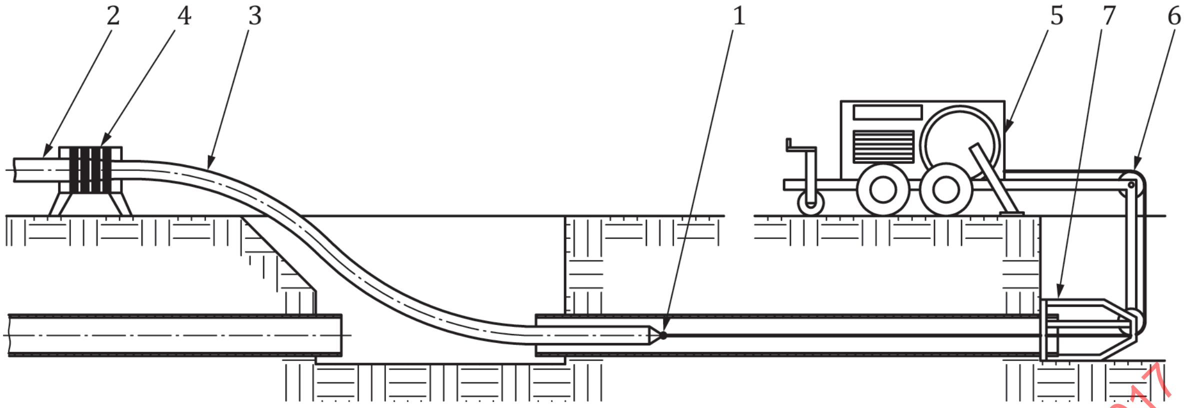


Key

1 drum trailer
2 pipe guide
3 lining pipe (folded)
4 pulling head
5 winch cable
6 winch
7 guide pulley
8 bracing

NOTE Pipe reverted (unfolded) after insertion by application of heat and/or pressure.

Figure 3 — Lining with close-fit pipes — Schematic representation of installation of a pipe reduced in external dimension in the pipe manufacturing plant (Method A)



Key

1 pulling head
2 initial lining pipe
3 reduced lining pipe
4 device for reducing
5 winch or rod pulling device
6 guide pulley
7 bracing cage

NOTE Pipe reverted (expanded or unfolded as applicable) after insertion by release of pulling force or application of pressure.

Figure 4 — Lining with close-fit pipes — Schematic representation of installation of a pipe reduced in external dimension on site (Method B)

Table 2 — Features of lining with close-fit pipes

Feature	Description
Relevant documents:	ISO 11296-3, ISO 11297-3, ISO 11298-3, ISO 11299-3
Materials:	PE and PVC-U
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— some deviation from nominally circular shape possible; — minimum size: 100 mm for both Method A and Method B; — maximum size: 500 mm for Method A, 1 500 mm for Method B; — maximum length: 500 m; — some techniques can accommodate bends.
Performance:	— minimal reduction in volumetric capacity; increase in flow due to reduced friction possible; — gradient cannot be restored; — structural rehabilitation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.
[a] Where reducing is carried out simultaneously with insertion, winching forces can be high, necessitating substantial anchoring of winch and reducing equipment.	

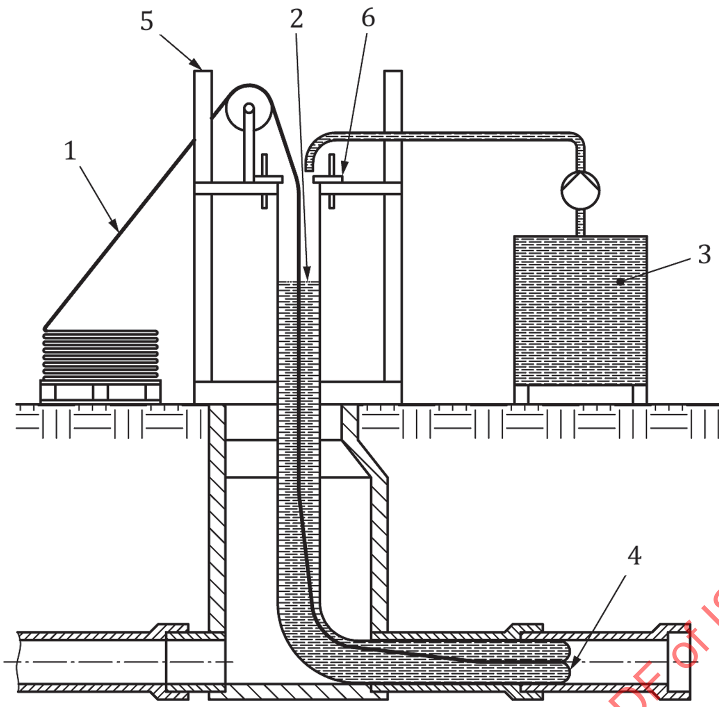
Table 2 *(continued)*

Feature	Description
Installation characteristics:	a) lining pipe first reduced in size by mechanical or thermo-mechanical means (in the manufacturing plant or on site), inserted (in the case of PVC-U pre-heating generally required) and then reverted by relief of installation forces or application of heat and/or pressure; b) surface working space: no particular constraint for Method A, storage of the whole insertion length can be required on surface for Method B (depends on specific technique); c) access: typically through manhole for Method A, requires local excavation for Method B; d) technique does not rely on adhesion to host pipe; e) flow diversion is required; f) grouting not applicable; g) reconnection of laterals: 1) gravity pipelines: possible from inside (re-opening and tight connection); 2) in pressure applications: generally requires excavation.
Installation equipment:	— rollers to support the entire length of the lining pipe string (except where pipe is inserted directly from a coil); — guide for entrance of the lining pipe into the existing pipeline; — winch to pull the lining pipe through the existing pipeline[a]; — pushing unit, if applicable; — a compressor and a steam generator (where applicable), or hydraulic pressurisation pump according to particular technique, for lining pipe reversion; — jointing equipment appropriate to material.
Surface area:	— for the lining pipe string (or coil trailer for smaller diameters and/or folded pipe) at the insertion end; — for reducing or folding equipment at the insertion end where reduction or folding is carried out simultaneously with insertion; — for a winch at the receiving end; — for reversion equipment.
Excavation:	— for Method A, not necessary for sewer applications, where access through existing manholes is sufficient due to flexibility of the lining pipe; in other applications, only small excavations at both ends; — for Method B, at the insertion end: long enough to allow the lining pipe to enter the existing pipeline, taking account of the permissible minimum bending radius; wide enough for the guidance equipment and pushing equipment, if applicable; — at the receiving end: large enough to accommodate the lining pipe nose cone and longitudinal retraction during reversion of the lining pipe, if applicable.

[a] Where reducing is carried out simultaneously with insertion, winching forces can be high, necessitating substantial anchoring of winch and reducing equipment.

6.4 Lining with cured-in-place pipes

Lining is carried out with a flexible tube impregnated with a thermosetting resin, which produces a pipe after resin cure [see Figure 5 (Method A), Figure 6 (Method B) and Table 3].



Key

1 impregnated lining pipe

2 applied water head for inversion

3 water reservoir

4 inversion face

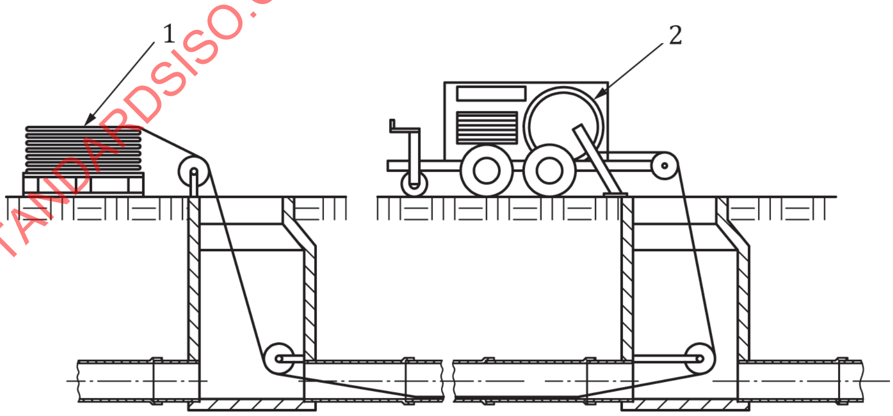
5 scaffold tower

6 clamping flange or ring

NOTE 1 The equipment used to cure resin on completion of inversion (e.g. by heating water or injecting steam) is not shown.

NOTE 2 Other methods, including inversion with air from a pressure vessel, are possible.

Figure 5 — Lining with cured-in-place pipes — Schematic representation of installation by inversion (Method A), showing use of scaffold tower and water



Key

1 impregnated lining pipe

2 winch

Figure 6 — Lining with cured-in-place pipes — Schematic representation of installation by winching and subsequent inflation (Method B)

Table 3 — Features of lining with cured-in-place pipes

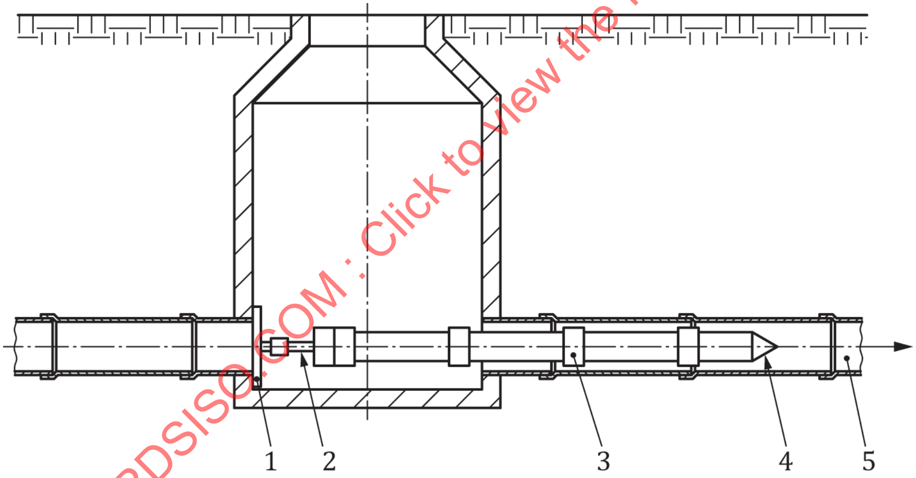
Feature	Description
Relevant documents:	ISO 11296-4, ISO 11297-4
Materials:	A composite consisting of a reinforced or unreinforced fabric carrier material impregnated with thermosetting resin (UP, EP or VE), which can include optional internal and/or external membranes. For details, see the relevant International Standard.
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— circular and non-circular cross-section; — minimum size: 100 mm; — maximum size: 2 800 mm; — maximum length: Method A: 600 m, Method B: 300 m; — bends can be accommodated; — change of dimensions can be accommodated.
Performance:	— minimal reduction in volumetric capacity; increase in flow due to reduced friction possible; — restoring of invert is not possible; — structural rehabilitation is possible; — abrasion resistance depends on wall structure; — chemical resistance mainly depends on resin type.
Installation characteristics:	a) insertion of the impregnated lining pipe, prior to curing, can be achieved by: 1) inverting into position with pressure only (water or air) or 2) winching into place and then inflating; 3) combinations of Methods A and B are also possible; b) curing process can be initiated or accelerated by either: 1) heat (hot water, steam); 2) UV radiation; 3) ambient temperature; c) surface working space: generally minimal, varies with technique; d) access: entry through existing manhole or small excavation possible; e) structural effect does not rely on adhesion to host pipe; f) flow diversion required; g) re-opening of laterals from inside is possible; h) reconnection of laterals: 1) gravity pipelines: possible from inside (re-opening and tight connection); 2) in pressure applications: generally requires excavation.

Table 3 *(continued)*

Feature	Description
Installation equipment:	— lining pipe delivery unit, including conveyor system, if applicable; — site impregnation unit, if applicable; — for inverted-in-place systems: water column or air compressor; — for winched-in-place systems: winch and water boiler or steam generator for heat curing, or equipment including power supply for UV.
Surface area:	— for lining pipe delivery unit immediately adjacent to the insertion access; — for site impregnation unit, if applicable; — for inversion or winching equipment; — for curing equipment.
Excavation:	— not generally necessary for sewer applications, where access through existing manholes is sufficient due to flexibility of the uncured lining pipe; — excavations at both ends for other applications.

6.5 Lining with discrete pipes

Lining is carried out with pipes shorter than the section to be renovated, which are jointed to form a continuous pipe only during insertion [see Figure 7 (Method A), Figure 8 (Method B), Figure 9 (Method C) and Table 4].



Key

1 thrust plate

2 pushing device

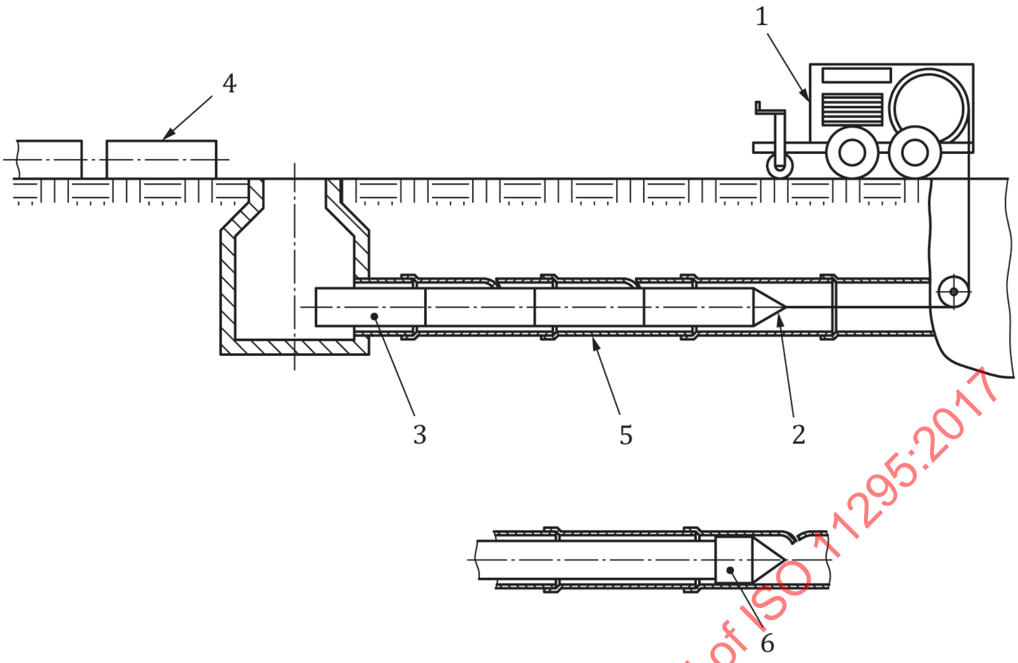
3 jointed lining pipe

4 pushing guide

5 existing pipe

NOTE The diameter of discrete pipes for insertion is slightly reduced against the existing pipe.

Figure 7 — Lining with discrete pipes — Schematic representation of installation by pushing (Method A)



Key

1 winch

2 pulling head

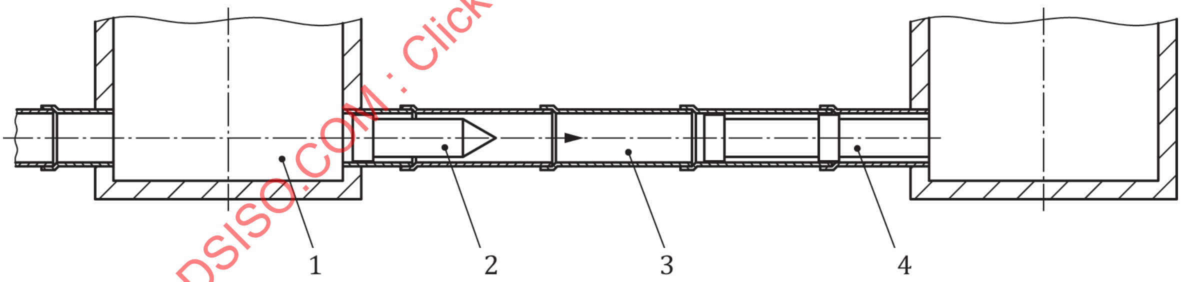
3 jointed lining pipe with end load bearing joints

4 stock of discrete pipes

5 existing pipe

6 re-rounding and pulling head

Figure 8 — Lining with discrete pipes — Schematic representation of installation by pulling (Method B)



Key

1 manhole

2 individual discrete pipe being pulled or pushed into place

3 existing pipe

4 pipes already in position

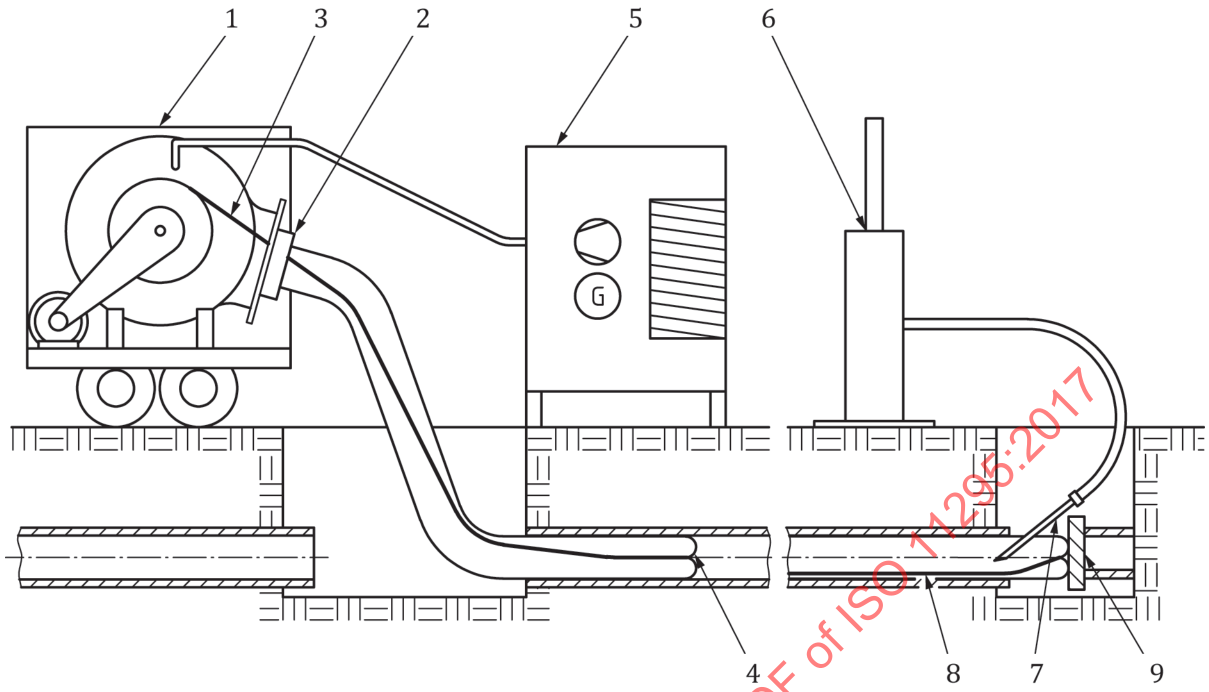
Figure 9 — Lining with discrete pipes — Schematic representation of installation by individual pipe placement (Method C)

Table 4 — Features of lining with discrete pipes

Feature	Description
Relevant documents:	ISO 10467, ISO 10639 and ISO 16611 for GRP; for other materials not yet available
Materials:	PE, PP, PVC-U, GRP
Applications:	— pressure pipes; — non-pressure pipes.
Geometric characteristics:	— circular and non-circular cross-section; — minimum size: Method A and B: 100 mm; Method C: 800 mm; — maximum size: Method A and B: 600 mm; Method C: 4 000 mm; — maximum length: 150 m; — bends: bends with large radii can be accommodated by Method C only.
Performance:	— significant reduction in hydraulic (volumetric and flow) capacity; — uniform gradient can be restored using Method C in man-entry pipes; — structural rehabilitation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.
Installation characteristics:	— the type of joint is a significant feature of each technique; — pipe joints can be locked (end load bearing) or unlocked; — surface working space: no particular constraint; — access to the existing pipeline: short pipe lengths can allow insertion from existing manholes (Methods A and B), but man-entry sizes installed by Method C can require local excavation; — technique does not rely on adhesion on host pipe; — flow diversion is typically required for installation and grouting; — the annular space is typically grouted; — reconnection of laterals: generally requires excavation; except in man-entry sizes.
Installation equipment:	— pipe handling equipment; — generator to power pipe jacking equipment.
Surface area:	— for storage of pipes, — for pipe handling equipment, — for a generator to power the pipe jacking equipment.
Excavation:	— not generally necessary for sewer applications, access through manhole due to availability of short pipe lengths; — for other applications, excavation large enough to accommodate jacking equipment at the insertion end; — man-entry access needed at receiving end.

6.6 Lining with adhesive-backed hoses

Lining is carried out with a reinforced hose which relies on an adhesive bond to the host pipe to provide resistance to collapse (see Figure 10 and Table 5).



Key

1 inversion unit
2 clamping flange
3 adhesive impregnated textile liner
4 inversion face
5 heating unit (steam boiler, compressor, generator)
6 steam exhaust
7 steam lance
8 retaining belt
9 bracing

Figure 10 — Schematic representation of lining with adhesive-backed hoses

Table 5 — Features of lining with adhesive-backed hoses

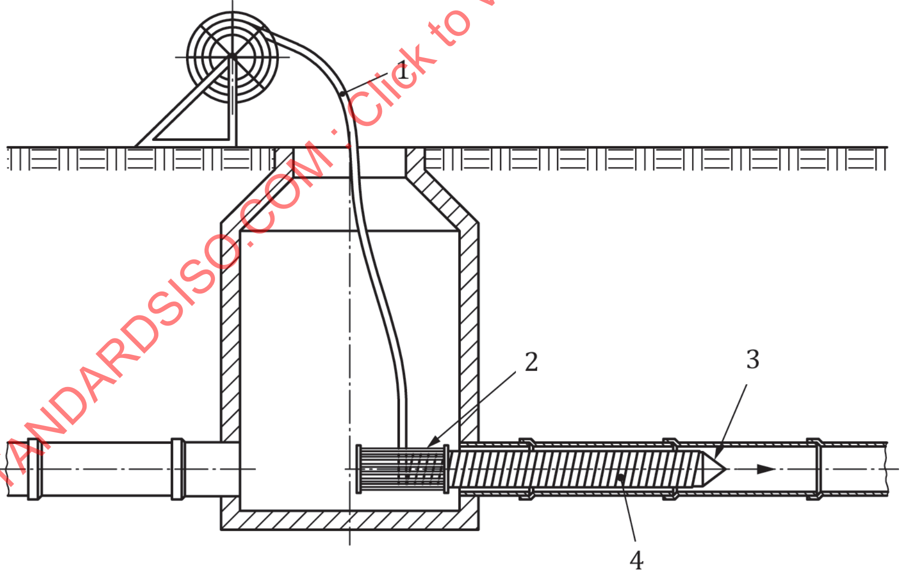
Feature	Description
Relevant documents:	Not yet available
Materials:	A circular woven hose coated on one side with a thermoplastic barrier layer and on the other with a thermosetting resin.
Applications:	Pressure pipes (water and gas)
Geometric characteristics:	— minimum size: 80 mm; — maximum size: 1 200 mm; — maximum length: 750 m; — bends can be accommodated.
Performance:	— minimal reduction of volumetric capacity; increase in flow possible; — structural rehabilitation is not possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.

Table 5 *(continued)*

Feature	Description
Installation characteristics:	— insertion of the adhesive-backed hose by inversion with air; — adhesive cured with heat or at ambient temperature; — surface working space generally minimal; — technique does rely on adhesion on host pipe; — flow diversion is required for installation; — re-opening of services and creation of a pressure-tight connection from inside is possible, relying on local adhesion of liner to existing pipe to seal annulus.
Installation equipment:	— at the insertion end, guide rollers; — at the receiving end, winch with trench mast; — a compressor or pre-compressed gas and heating unit for hose reversion, if applicable.
Surface area:	— for drums of lining hose at the insertion end; — for inversion unit; — for heating unit, if applicable.
Excavation:	— small access excavation sufficient due to flexibility of hose.

6.7 Lining with spirally-wound pipes

Lining is carried out with a profiled strip, spirally wound to form a continuous pipe after installation [see Figure 11 (Method A1), Figure 12 (Method A2), Figure 13 (Method B) and Table 6].



Key

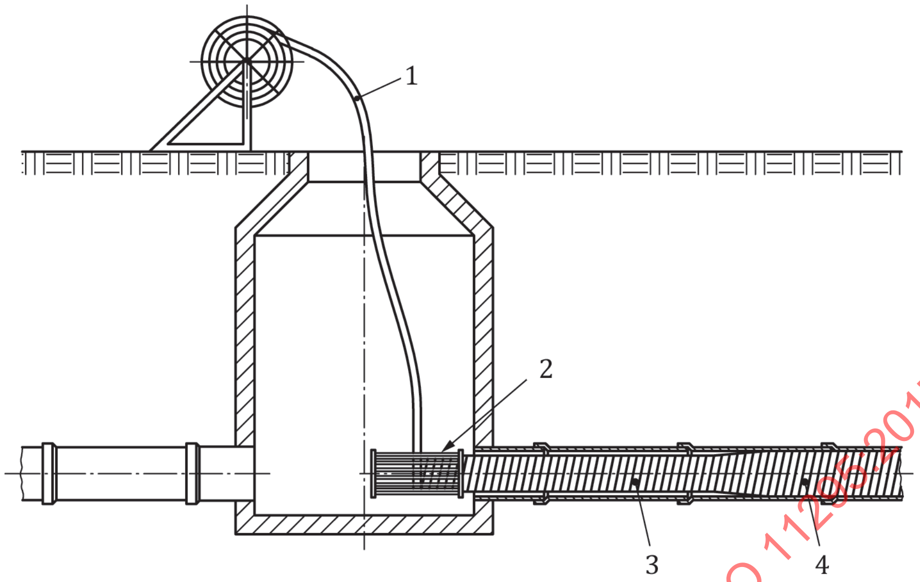
1 plastics strip to be spirally wound

2 guidance head (where applicable)

3 winding machine in the manhole

4 spirally-wound lining pipe

Figure 11 — Lining with spirally-wound pipes — Schematic representation of fixed diameter winding from the manhole (Method A1)



Key

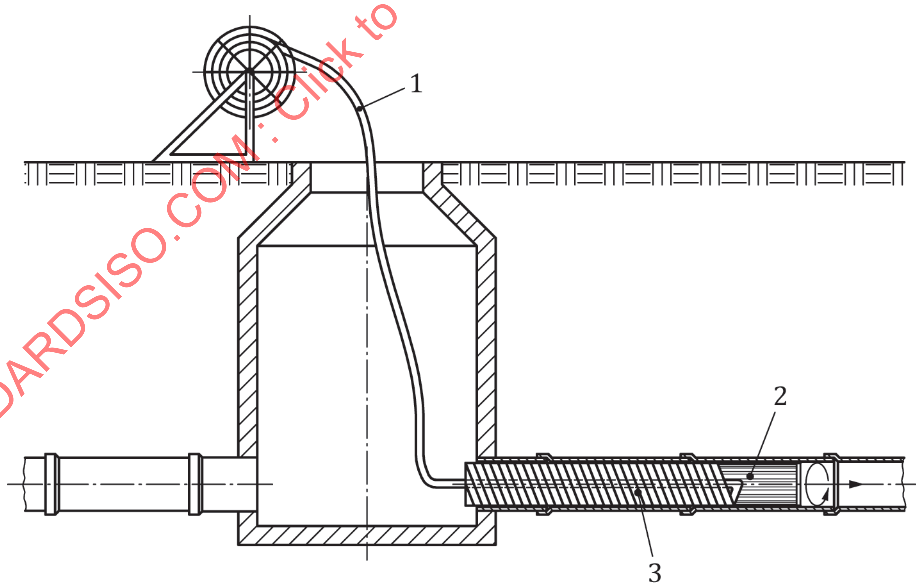
1 plastics strip to be spirally wound

2 winding machine in the manhole

3 spirally-wound lining pipe temporarily locked at reduced diameter for insertion

4 expanded diameter

Figure 12 — Lining with spirally-wound pipes — Schematic representation of expanded liner winding from the manhole (Method A2)



Key

1 plastics strip to be spirally wound

2 winding machine in the pipe

3 spirally-wound liner

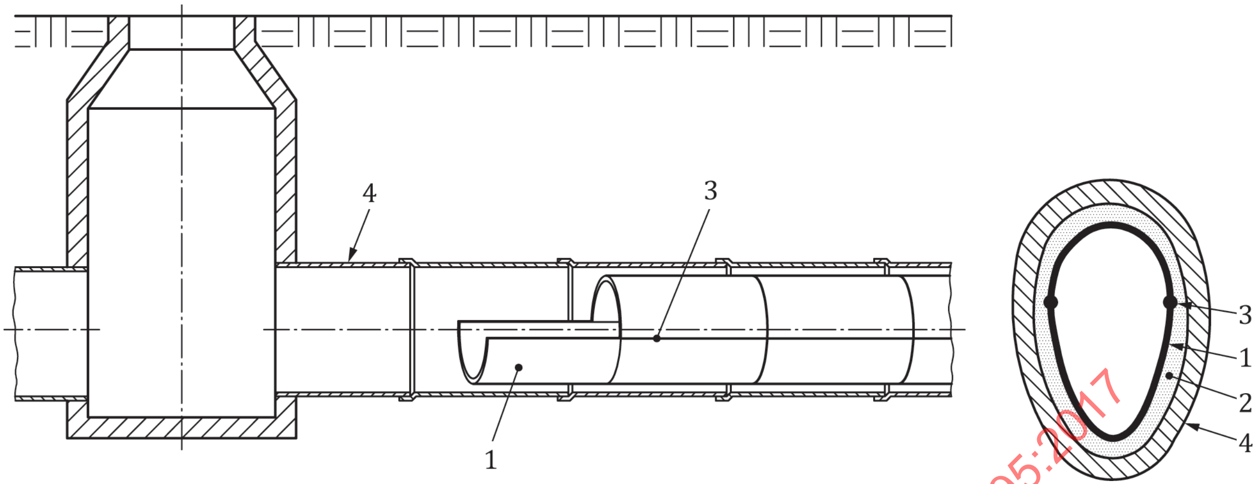
Figure 13 — Lining with spirally-wound pipes — Schematic representation of winding of liner from pipe-traversing winding machine (Method B)

Table 6 — Features of lining with spirally-wound pipes

Feature	Description
Relevant documents:	ISO 11296-7
Materials:	PVC-U, PE, optional steel reinforcement
Applications:	— non-pressure; — applicable for manholes.
Geometric characteristics:	— Method A circular cross-section only; Method B adaptable also to non-circular sections; — minimum size: 150 mm for Method A; 800 mm for Method B; — maximum size 3 000 mm for Method A, 1 800 mm for Method B[a]; — maximum length: 300 m; — bends can be accommodated.
Performance:	— reduction in capacity dependent on annular space and ratio of diameter to overall profile height; — uniform gradient can generally not be restored; — structural renovation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.
Installation characteristics:	— lining pipe formed on site by spirally winding a strip, which is jointed and sealed by solvent welding and/or mechanical means; — individual winding machines can produce a range of diameters; — no pipe storage on site; — surface working space generally minimal; — access through manholes possible; — technique does not rely on adhesion to host pipe; — flow diversion during installation is required for grouting and installation; — grouting of annular space is required for fixed diameter; — for (re)connection of laterals in non-man-entry pipes, local excavation is generally required; reconnection from the inside is also possible.
Installation equipment:	— strip winder; — grouting equipment (if applicable).
Surface area:	— for drums of liner strip at the insertion end; — for a generator to power the winder at the insertion end.
Excavation:	— manhole access sufficient due to flexibility of lining strip and small size of the winder.
[a] Larger sizes are possible with steel reinforcement.	

6.8 Lining with pipe segments

Lining carried out with prefabricated segments bonded to the existing pipe (see Figure 14 and Table 7), which have longitudinal joints.



Key

1 lining pipe segments

2 grout

3 longitudinal joints

4 existing pipe

Figure 14 — Schematic representation of lining with pipe segments

NOTE Partial lining, not covering the whole circumference of the pipeline, is outside the scope of this document.

Table 7 — Features of lining with pipe segments

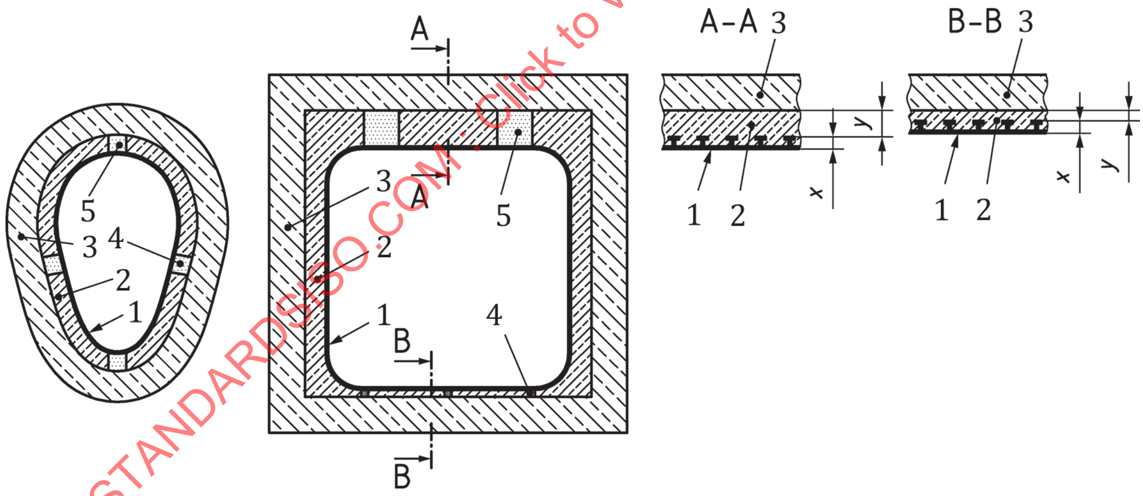
Feature	Description
Relevant documents:	Not yet available
Materials:	GRP, PRC
Applications:	— non-pressure pipes;
Geometric characteristics:	— circular and non-circular cross-section; — minimum size: man-entry sewer only; — maximum size: no limit; — maximum length: no limit; — bends can be accommodated; — change of dimensions can be accommodated.
Performance:	— hydraulic performance: reduction in capacity dependent on annular space and thickness in relation to diameter; uniform gradient can be restored; — structural enhancement: structural renovation is possible; — abrasion and chemical resistance: liner pipe material determines abrasion and chemical resistance.

Table 7 *(continued)*

Feature	Description
Installation characteristics:	— jointing by either mechanical interlock or laminate/bonding; — lining pipe segments prefabricated or shaped in place; — mechanical link to host pipe using grouting, gluing and/or anchoring is required; — surface working space minimal at access point, but site storage for segments required; — access through manholes is possible; — flow diversion dependent on safety requirements due to man entry; — grouting of annular space is required; — reconnection of laterals is possible from inside.
Installation equipment:	— winch; — grouting equipment (if applicable).
Surface areas:	— for material storage at the insertion end; — for a generator to power the winch at the receiving end.
Excavation:	— manhole access sufficient.

6.9 Lining with a rigidly anchored plastics inner layer

Lining is carried out with a single rigid annulus of structural cementitious grout formed between the host pipe and a plastics inner layer with integral ribs or studs permanently anchored to the grout (see Figure 15 and Table 8). This technique family relies on the rigid annulus of grout for its structural performance.



Key

1 anchored plastics inner layer
2 grout system
3 existing pipe
4 spacer (technique dependent)
5 anti-flotation spacers
x height of anchors
y minimum thickness of grout above height of anchors

Figure 15 — Typical wall construction of a lining system with plastics inner layer rigidly anchored in structural cementitious grout

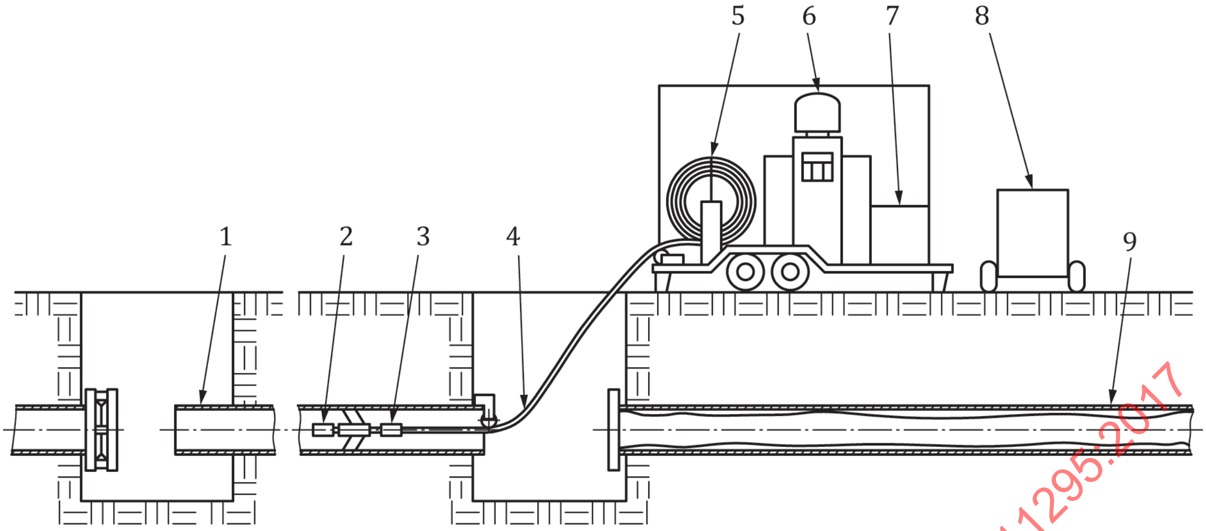
Different types of internal plastics layer are used by different techniques. In addition to tubes of studded plastics sheeting winched in place and inflated prior to grouting, these include discrete pipes of plastics materials installed according to 6.5, as well as profiled plastics strips formed into a pipe by spirally winding according to 6.7 or by other means and pipe segments of plastics materials according to 6.8, where structural performance depends on permanent anchorage of the plastics component to a rigid annulus of cementitious grout.

Table 8 — Features of lining with a rigidly anchored inner plastics layer

Feature	Description
Relevant documents:	EN 16506
Materials:	Inner layer of PE, PP or PVC-U, with a structural cementitious grout with or without reinforcement, and optional outer plastics layer
Applications:	— non-pressure pipes;
Geometric capabilities:	— circular and non-circular cross-section; — minimum size: 200 mm but technique dependent; — maximum size: 2 000 mm[a]; — maximum length: 200 m; — bends can be accommodated.
Performance:	— reduction in capacity dependent on annular space and ratio of diameter to overall profile height; — uniform gradient can generally not be restored; — structural renovation is possible (depending on the strength of the grout); — inner plastics layer material determines abrasion resistance; — mechanically anchored inner plastics layer determines chemical resistance.
Installation characteristics:	— surface working space is generally minimal; — access is generally possible through manholes; — technique does not rely on adhesion to host pipe; — requires flow diversion and absence of groundwater infiltration; — grouting of annular space part of this technique; — reconnection of laterals is possible from inside, if outer plastics layer used.
Installation equipment:	— winch (if applicable); — grouting equipment.
Surface area:	— for material storage at the insertion end; — for a generator to power the winch at the receiving end.
Excavation:	— manhole access usually sufficient.
[a] Sizes up to 5 000 mm are possible with certain specialized techniques and materials.	

6.10 Lining with sprayed polymeric materials

Lining is carried out by spraying a layer of a polymeric material typically 3 mm thick or greater onto the internal surface of the pipeline (see Figure 16 and Table 9). This technique family relies for its structural performance on the existing pipeline.



Key

1 lined pipe
2 lining head
3 static mixer
4 base/activator/air supply hose
5 hose drum/winch
6 metering pump
7 reservoirs
8 air compressor and generator
9 existing pipe with encrustation still to be cleaned and lined

Figure 16 — Lining with sprayed polymeric materials

Derived from the traditionally used spray method using cement mortar, different techniques are in use, applying polymeric materials.

Table 9 — Features of lining with sprayed polymeric materials

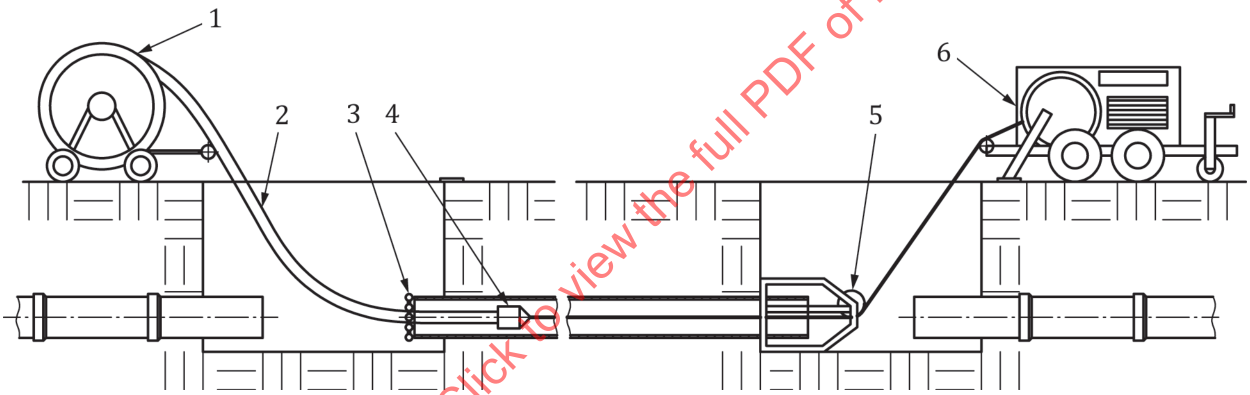
Feature	Description
Relevant documents:	Not yet available
Materials:	Polymeric two-part resin systems (PUR, EP)
Applications:	— pressure pipes
Geometric capabilities:	— minimum size: 75 mm; — maximum size: 600 mm; — maximum length: 150 m.
Performance:	— minimal reduction in capacity; — Class B semi-structural renovation; — polymeric layer material determines abrasion resistance.
Installation characteristics:	— surface working space is generally minimal; — service connections generally not blocked provided they are blown through immediately after lining; — technique requires aggressive cleaning of internal surface of host pipe to provide a hydraulically smooth finish; — moisture tolerant but requires host pipe to be taken out of service and drained down; — short 2 h curing period possible, allowing same day return to service.

Table 9 *(continued)*

Feature	Description
Installation equipment:	— aggressive pipe cleaning equipment; — settling tank; — CCTV equipment; — spray unit; — compressor.
Surface area:	— space for cleaning equipment, settling tank, compressor and spray unit at the insertion end.
Excavation:	— access excavations for insertion end and receiving end.

6.11 Lining with inserted hoses

Lining with a circular woven reinforced textile which is either permanently restructured to provide a pipe after installation or inflates when fluid is transported under pressure, without bonding to the existing pipe (see Figure 17 and Table 10).



Key

1 drum and dispensing unit
2 hose to be inserted
3 insertion roller
4 pulling head
5 guide roller
6 winch

Figure 17 — Schematic representation of lining with inserted hoses

Table 10 — Features of lining with inserted hoses

Feature	Description
Relevant documents:	Not yet available
Materials:	A circular woven hose of synthetic fibres, with coatings of the same or different thermoplastic materials on the inside and outside
Applications:	— pressure pipes; water and gas supply pipelines
Geometric characteristics:	— minimum size: 80 mm; — maximum size: 500 mm; — maximum length: 2 km.

Table 10 *(continued)*

Feature	Description
Performance:	— the liners have full internal pressure resistance; — minimal reduction in volumetric capacity; — abrasion and chemical resistance: inside of liner determines abrasion and chemical resistance;
Installation characteristics:	— the lining pipe is pulled in by forming it into a U-shape; — reversion by applying internal pressure (compressed air); — the liner is not bonded to the existing pipe, but will stay round under depressurized conditions, provided that it is not subject to external load.
Installation equipment:	— winch; — compressor.
Surface areas:	— winch at receiving end; — drums with coiled material and dispensing unit at the insertion end.
Excavation:	— access excavation for insertion end and receiving end.

7 Classification of trenchless replacement techniques

7.1 General

Replacement technique families within the scope of this document are shown in Figure 1.

This clause establishes a classification of techniques into families, where replacement is applied to continuous lengths of existing pipeline usually between two or more access points.

Individual techniques shall be classified into families according to 7.2 to 7.6 where the different replacement technique families are defined and their respective features, including materials, applications, as well as geometric, performance and installation characteristics, are described.

NOTE 1 The pipe materials listed in 7.2 to 7.6.3 reflect the state-of-the-art in the technique families on the date of publication of this document. Not all technique families/material-combinations are covered by a product standard. The Bibliography gives relevant available document.

NOTE 2 The application areas covered by existing product standards include underground drainage and sewerage, and underground water and gas supply networks. This document is not applicable to other possible areas of application of the technique families described.

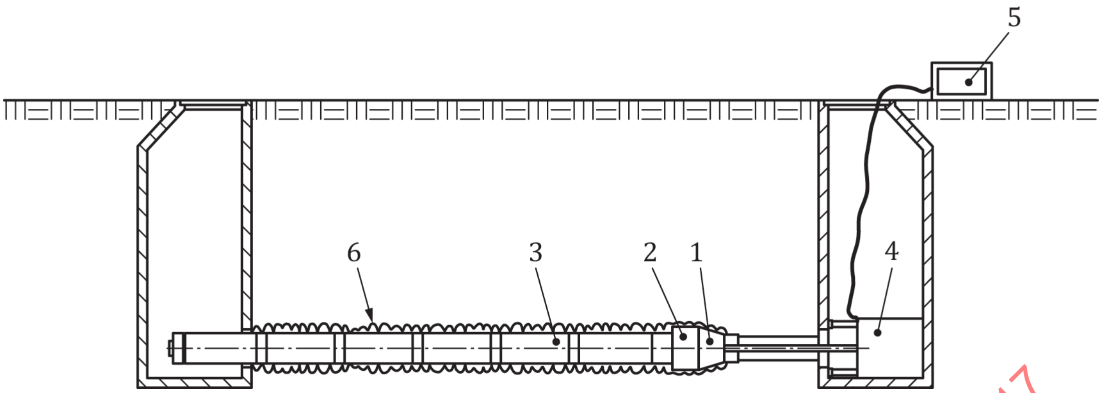
7.2 Pipe bursting

Replacement is done by bursting or splitting the existing pipe, and displacing it into the surrounding ground, while simultaneously pulling in a new continuous or discrete pipe, of the same or larger diameter.

A bursting head with a cone with or without fixed blades is generally used for brittle pipe materials such as clay, grey cast iron or fibre cement, whereas a splitting head with cutting discs is generally used for non-brittle pipe materials such as ductile iron, steel or plastics. Both types of head embody an expansion cone to displace the existing burst or split pipe into the surrounding ground and form a bore for the new pipe [see Figure 18 (Method A), Figure 19 (Method B) and Table 11].

Methods used are static pipe bursting (Method A) or dynamic pipe bursting (Method B).

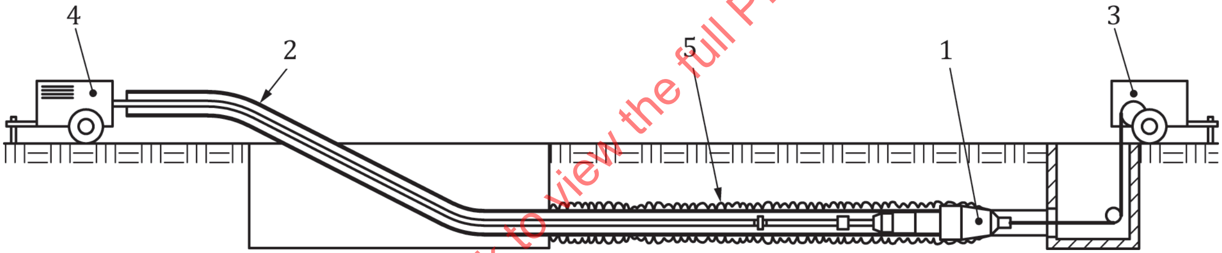
NOTE Dynamic pipe bursting creates shock waves in the surrounding ground with the potential to damage adjacent infrastructure. For some cases, e.g. large diameter concrete pipes, the bursting forces can be very high and the use of a pneumatic hammer potentially dangerous. For such applications, a hydraulic bursting head can be used, in which the bursting blades are expanded and contracted sequentially as it is pulled along.



Key

1 bursting head
2 expander cone
3 jointed lining pipe
4 pulling rig
5 hydraulic unit
6 pipe fragments

Figure 18 — Schematic representation of replacement by static pipe bursting (Method A: Installing discrete pipes)



Key

1 bursting head/expander and hammer
2 continuous lining pipe
3 cable winch
4 air compressor/hydraulic power unit
5 pipe fragments

Figure 19 — Schematic representation of Installation by dynamic pipe bursting (Method B: Installing continuous pipes)

Table 11 — Features of replacement by pipe bursting

Feature	Description
Relevant documents:	ISO 21225-1, EN 12889
Materials new pipe:	PE, PP, GRP, PVC-U
Materials host pipe:	— all materials except pre-stressed concrete pipes;
Applications:	— non-pressure pipes; — pressure pipes.

Table 11 *(continued)*

Feature	Description
Geometric characteristics:	— the technique can also be used with severely deformed nominally circular host pipe cross-sections; — minimum size: 50 mm; — maximum size: 1 000 mm; — maximum length: 250 m; — bends with large radii can be accommodated, subject to pipe size and flexibility of pulling rods.
Performance:	— minimal or no reduction in hydraulic capacity, hydraulic (volumetric and flow) capacity can be increased; — uniform gradient cannot generally be restored; — abrasion resistance depends on pipe material; — chemical resistance depends on pipe material.
Installation characteristics:	— typically pipes manufactured or prior assembled into the continuous length; discrete pipes also possible; — insertion by pulling; forces can be recorded/limited; — surface working space: storage of the whole insertion length required on surface (continuous pipe); no particular constraint (discrete pipe); — access to the existing pipeline: typically requires local excavation; access through manhole generally also possible; — isolation of existing pipeline required prior to bursting; — flow diversion typically required for installation; — lateral connections need to be cut or disconnected before the bursting operation; — reconnection of laterals: generally requires excavation.
Installation equipment:	— rollers to support the entire length of the lining pipe string (except where the pipe is inserted directly from a coil); — rollers to guide the lining pipe into the existing pipeline; — for Method A, rod pulling device to propel bursting head through the existing pipeline; — for Method B, winch to maintain the alignment of the bursting head through the existing pipeline; — jointing equipment appropriate to the material; — bursting/splitting head; — hydraulics or pneumatics in case of dynamic bursting.
Surface area:	— for the lining pipe string (or coil trailer for smaller diameters) at the insertion end; — in the case of Method B, for a winch at the receiving end, and an air compressor at the insertion end.

Excavation:	— at the insertion end:
	  — long enough to allow the lining pipe to enter the existing pipeline, taking account of the permissible minimum bending radius given by the manufacturer in dependence of the pipe dimension and the temperature;
	— at the receiving end:
	  — large enough to accommodate the lining pipe nose cone and the winch mast or rod pulling unit, as applicable.

7.3 Pipe removal

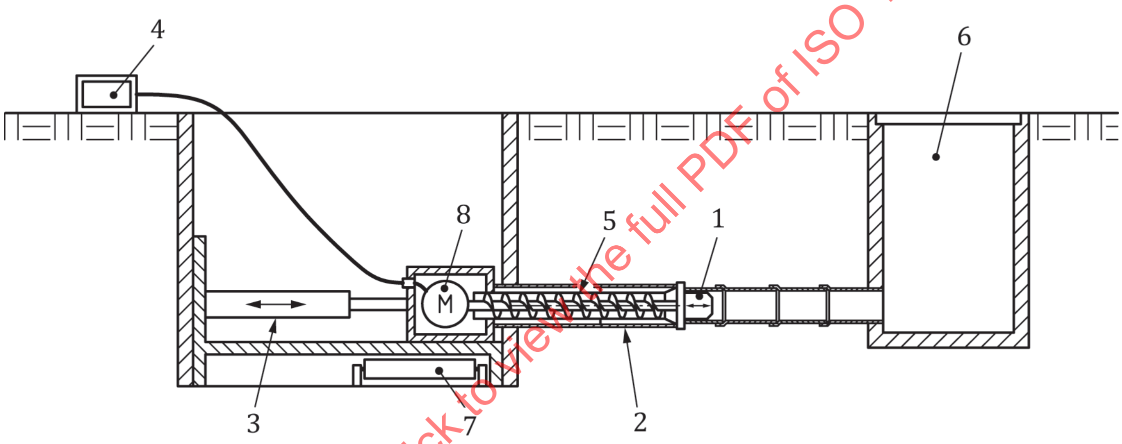
7.3.1 General

Replacement is carried out by destroying the existing pipe, conveying the fragments above ground, and subsequently installing a new discrete pipe of a same or larger diameter than the existing pipe [see Figure 20 (Method A), Figure 21 (Method B) and Table 12].

Methods used are pipe eating (Method A) or pipe extraction (Method B).

7.3.2 Pipe eating

Method A uses a microtunnelling machine to break up the existing pipe and an auger or slurry system to extract the pipe fragments together with the surrounding ground if enlargement is required. New discrete pipe sections are pushed in behind. The tunnelling machine shield can have an extended guide running within the old pipe to keep the machine centred, and can incorporate a seal to prevent slurry going forward.



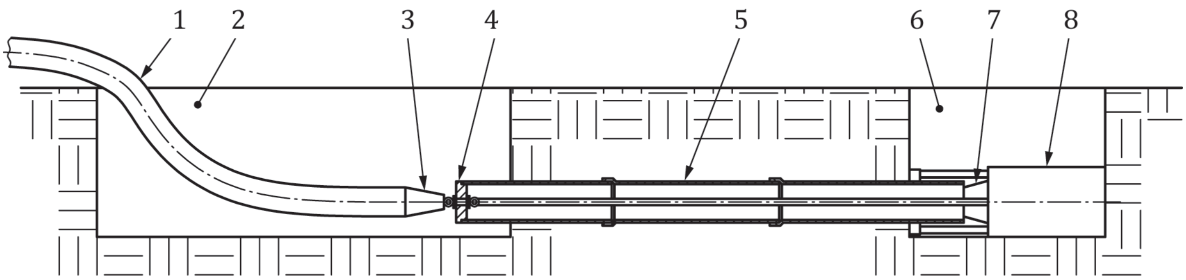
Key

1	microtunnelling machine	5	auger
2	auger casing	6	target pit
3	driving unit in starting pit	7	spoil skip
4	hydraulic unit	8	auger drive motor

Figure 20 — Schematic representation of replacement by pipe eating method (Method A)

7.3.3 Pipe extraction

Method B uses a rod puller to pull the old pipe through the ground, removing or bursting old pipe sections as they arrive at the rod puller, while simultaneously pulling in new pipe. This would typically be used for pressure pipes, as it allows installation of continuous pipe, and leaves behind no shards of old pipe. Due to the high friction forces, only a short length of pipe can be extracted between pits.



Key

1 new pipe
2 entry pit
3 nose cone
4 pipe extraction adapter
5 existing pipe; pulling rod inserted
6 exit pit
7 pipe splitting / cracking cone
8 hydraulic rod pulling device

Figure 21 — Schematic representation of replacement by pipe extraction method (Method B)

Table 12 — Features of replacement by pipe removal

Feature	Description
Relevant documents:	ISO 21225-1, EN 12889
Materials new pipe:	Method A: GRP, PRC Method B: PE, PP
Materials host pipe:	Method A: vitrified clay, non-reinforced concrete; fibre cement, cast iron Method B: steel, cast iron, ductile iron, lead
Applications:	— pressure pipes; — non-pressure pipes, Method A only;
Geometric characteristics:	— circular host pipe only; — minimum size: Method A: 100 mm; Method B: 20 mm; — maximum size: Method A: 800 mm; Method B: 400 mm; — maximum length: Method A: 80 m; Method B: 30 m; — bends cannot be accommodated with Method A; with Method B possible to accommodate bends by use of intermediate pits.
Performance:	— no reduction in hydraulic capacity, hydraulic (volumetric and flow) capacity can be increased; — uniform gradient can be restored with Method A; not with Method B; — abrasion resistance depends on pipe material; — chemical resistance depends on pipe material.

Table 12 *(continued)*

Feature	Description
Installation characteristics:	— only discrete pipes can be installed with Method A; with Method B also continuous pipes; — insertion by pushing with Method A; by pulling with Method B; — significant surface space necessary with Method A for pipe eating equipment; with Method B no constraint for discrete pipe, and for continuous pipe sufficient storage for the whole part of insertion length; — access to the existing pipeline: typically requires local excavation; — isolation of existing pipeline required prior to displacement; — flow diversion typically required for installation; — lateral connections need to be cut or disconnected before pipe removal; — annular space typically has to be grouted with Method A; — reconnection of laterals: generally requires excavation for both methods.
Installation equipment:	— pipe handling equipment; — with Method A: — microtunnelling machine including auger or slurry system; — slurry mixing unit; — generator to power the microtunnelling machine; — with Method B: — winch (cable or rod pulling); — rollers with continuous pipe to support the entire length of the pipe string (except where pipe is inserted directly from a coil); — jointing equipment appropriate to the material.
Surface area:	— for a microtunnelling machine at the receiving end; — for a generator to power the microtunnelling; — for slurry mixing unit; — for storage of pipes; — for pipe handling equipment.
Excavation:	— at the insertion end: large enough to accommodate the microtunnelling machine and pipe jacking frame with Method A and the pipe pulling machine with Method B; — at the receiving end: large enough to retrieve the microtunnelling machine with Method A and to allow man-entry access with Method B.

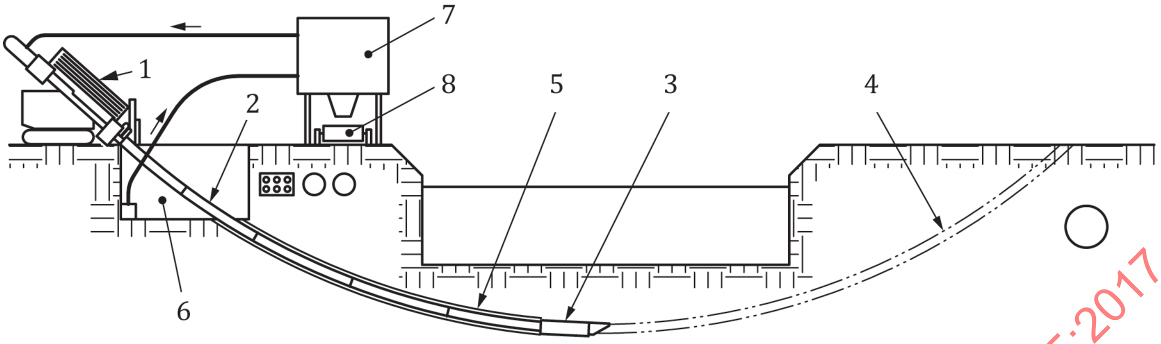
7.4 Horizontal directional drilling — HDD

Replacement is carried out off the existing pipe-line by using a steerable installation technique (see Figure 22, Figure 23 and Table 13).

HDD is using a machine in which flexible rods are rotated and pushed, propelling a cutter which is generally slant headed through the ground. Steering is accomplished by the reaction of the slant head against the ground when pushed without rotation. Supported by a location device, this enables a pilot hole to be established to a planned line and grade, after which the hole is enlarged by pulling back a rotating reamer. Simultaneously or in a separate process the product pipe is pulled into the bore hole.

There are many different types of cutter to enable steering capability to be maintained in difficult ground conditions such as rock, where a slant head cutter will not work effectively. No steering is done with reamers.

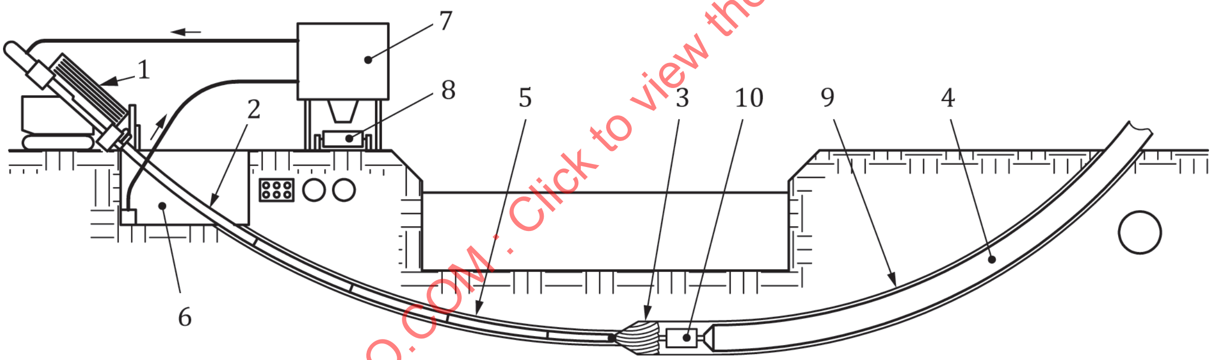
When drilling, the soil or rock cuttings always need to be removed. As drilling proceeds, this is carried out from the hole by the drilling fluid that is continually pumped down the drilling rods, serving also to cool the cutter/reamer, and support the hole to prevent it collapsing.



Key

1 drill rig
2 drill string
3 drill head
4 planned bore path
5 pilot bore
6 mud sump
7 mud recycling and spoil separation unit
8 spoil skip

Figure 22 — Schematic representation of replacement by horizontal directional drilling — Pilot bore



Key

1 drill rig
2 drill string
3 back reamer
4 new pipe
5 pilot bore
6 mud sump
7 mud recycling and spoil separation unit
8 spoil skip
9 final bore
10 spinner

Figure 23 — Schematic representation of replacement by horizontal directional drilling — Pipe installation

Table 13 — Features of replacement by HDD

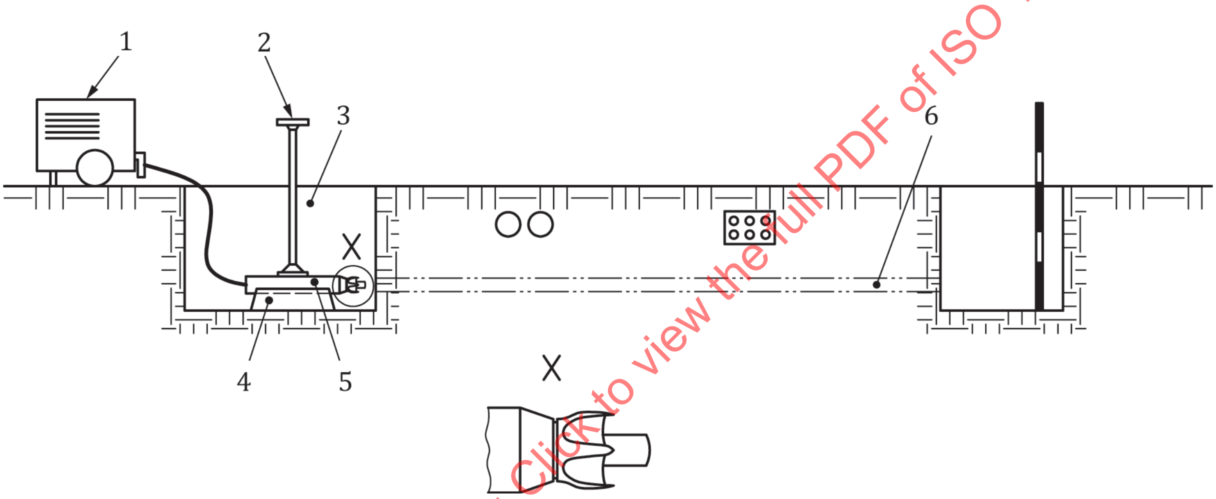
Feature	Description
Relevant documents:	ISO 21225-2, EN 12889
Materials:	PE
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— circular cross-section; — minimum size: 50 mm; — maximum size: 1 200 mm; — maximum length: 2 000 m.
Performance:	— no reduction in hydraulic capacity, hydraulic capacity (pipe diameter) can be increased; — steerable; — hydraulic gradient can be restored; — abrasion resistance depends on pipe material; — chemical resistance depends on pipe material.
Installation characteristics:	— typically pipes manufactured or prior assembled into the continuous length; — insertion by pulling; — surface working space: a) storage of the whole insertion length required on surface (continuous pipe); b) space for drilling fluid mixing tanks, pumps, treatment and recycling; c) control room, slurry treatment system, storage of discrete pipes; — connection of laterals: generally requires excavation.
Installation equipment:	— drilling machine; — generator; — fluid mixing unit; — location device; — rollers for continuous pipes to support the entire length of the pipe string (except where pipe is inserted directly from a coil); — jointing equipment for continuous pipes appropriate to the material; — pipe handling equipment.
Surface area:	— for a drilling machine at the receiving end; — for a fluid mixing unit at the receiving end; — for a drilling fluid recycling system where required; — for pipe handling equipment; — for storage of pipes; — for the pipe string (or coil trailer for smaller diameters) at the insertion end.
Excavation:	— at the insertion end: — long enough to allow the pipe to enter the ground, taking account of the permissible minimum bending radius; — at the receiving end: — long and large enough to allow drilling launch, to accommodate the pipe nose cone, reamer and swivel, and to provide the sump for pumping returning mud to the recycling unit.

7.5 Impact moling

Replacement is carried out off the existing pipeline using a percussive soil displacement hammer or impact mole (see Figure 24 and Table 14).

Impact moling is a technique, generally considered to be non-steerable, using a pneumatic powered torpedo shaped device, known as a mole. This incorporates a reciprocating internal hammer impacting on the back of a nose cone which in some cases can move independently of the main body. The friction between the main body and the ground enables the nose cone to move forward at each hammer blow, while the length of the main body keeps the mole on line. There are several designs of nose cone, which claim to give better penetration, or to be less susceptible to being pushed off line by lumps of stone.

Because the excavated material has to be forced out into the surrounding ground, this technique is confined to small pipe diameters, typically service pipes. The pipe is generally pulled in behind the mole, or can be pulled back as the mole is reversed out. A pneumatic mole has lubricating oil injected into the air supply, so in the case of clean water applications, care shall be taken to prevent exhaust air getting into the pipe being installed; inserting the new pipe by pulling back as the mole is reversed minimizes this risk.



Key

1 air compressor
2 aiming device
3 entry pit
4 launch cradle
5 impact mole
6 planned bore path

Figure 24 — Schematic representation of replacement by impact moling

Table 14 — Features of replacement by impact moling

Feature	Description
Relevant documents:	ISO 21225-2, EN 12889
Materials:	PE
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— circular cross-section: — minimum size: 25 mm; — maximum size: 160 mm; — maximum length: 25 m;

Table 14 *(continued)*

Feature	Description
Performance:	— hydraulic gradient can be restored within limits; — abrasion resistance depends on pipe material; — chemical resistance depends on pipe material.
Installation characteristics:	— applicable in displaceable soils only; — typically pipes manufactured or prior assembled into the continuous length; discrete pipes; — insertion by pulling; — surface working space: no particular constraints; — connection of laterals: generally requires excavation.
Installation equipment:	— pneumatic hammer, a cylinder with tapered or stepped head; — air compressor to power the hammer; — aiming and launching equipment; — rollers for continuous pipes to support the entire length of the pipe string (except where pipe is inserted directly from a coil); — jointing equipment for continuous pipes appropriate to the material; — pipe handling equipment.
Surface area:	— for a compressor to power the hammer; — for pipe handling equipment; — for storage of pipes; — for the pipe string (or coil trailer for smaller diameters) at the insertion end.

Excavation:	— at the insertion end:
	    — long enough to allow the pipe to enter the ground, taking account of the permissible minimum bending radius, if the pipe is to be pulled in behind the mole;
	— at the receiving end:
	    — large enough to accommodate the pneumatic hammer.

7.6 Pipe jacking

7.6.1 General

Methods used are auger boring and microtunnelling (see Figure 25, Figure 26 and Table 15).

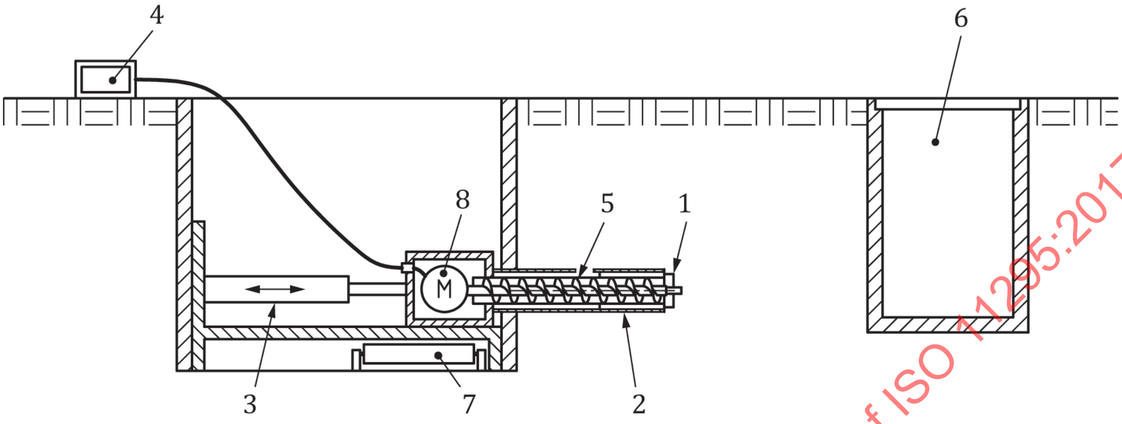
7.6.2 Auger boring

Replacement is carried out in displaceable ground, generally off the line of the existing pipeline, by using a non-steerable or a steerable (guided) installation technique.

NOTE Pipe eating (see 7.3.2) uses very similar equipment to achieve replacement on the line of the existing pipeline.

With non-steerable auger boring, a jacking machine pushes discrete pipe sections through the ground, and drives the cutter head through an auger running inside the pipe. The excavated soil is brought out by the auger, and discharged into a tub under the machine bed, and as the pipe advances, new pipe sections and new auger sections are added. If required, the auger sections may incorporate their own pipe enclosure, so as to prevent the excavated material damaging the internal surface of the new pipe.

With guided auger boring, firstly pilot rods are rotated and jacked through the ground, propelling a cutting head which is generally slant-faced. Steering is accomplished by the reaction of the slant head against the ground when pushed without rotation. Supported by a location device, this enables a pilot hole to be established to a planned line and grade. Once the pilot rods are installed, the pilot bore is enlarged by casings with an auger continuously removing the soil and guided by the pilot rods. The product pipes are then installed while pushing the casings out of the ground.



Key

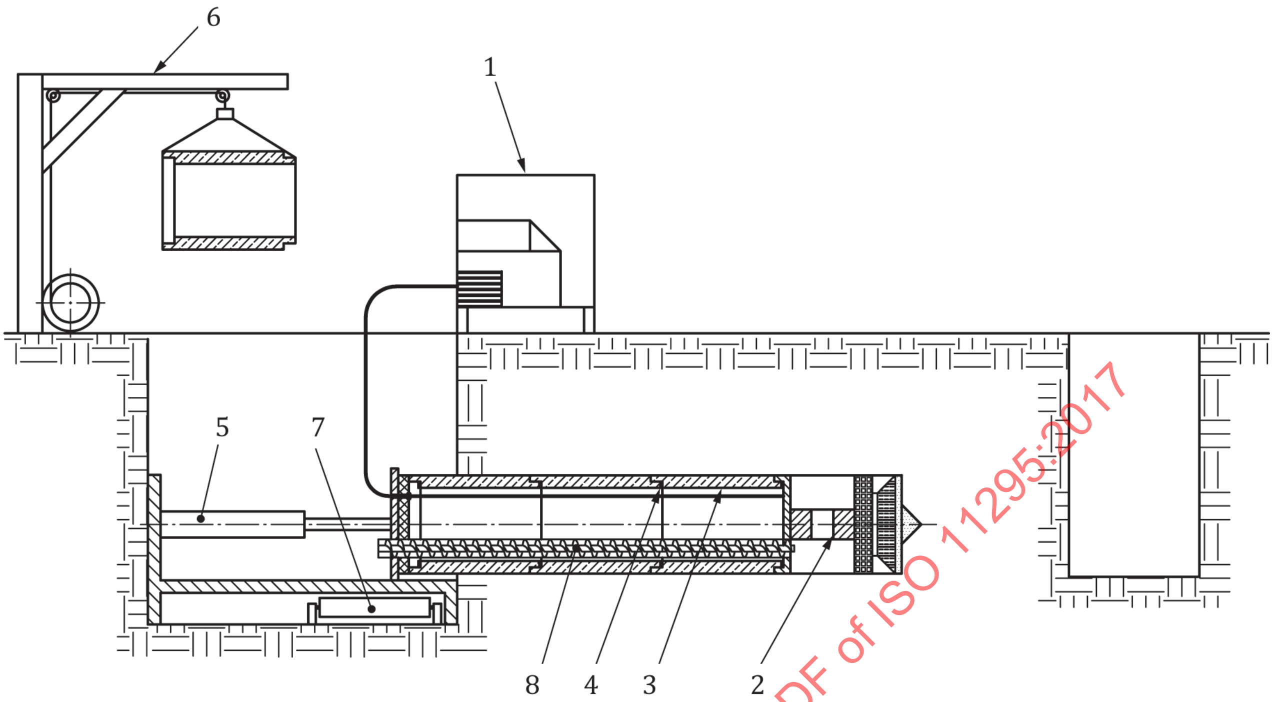
1 cutting head
2 auger casing
3 driving unit in starting pit
4 hydraulic unit
5 auger
6 target pit
7 spoil skip
8 auger drive motor

Figure 25 — Trenchless replacement by pipe jacking — Schematic representation of replacement by (non-steerable) auger boring

7.6.3 Microtunnelling

Replacement is carried out off the existing pipeline using hydraulic jacks to push discrete pipes through the ground behind a remotely controlled microtunnelling boring machine which is used to excavate soil or rock to form a bore.

Microtunnelling is a remotely controlled form of pipe jacking specifically designed for non-man-entry size pipes. Entry and reception shafts shall be excavated and a thrust wall shall be constructed in the entry shaft to provide support for the boring machine. The excavation face is supported by applying mechanical or fluid pressure to balance groundwater and earth pressures. The boring machine is operated remotely from the surface from where precise grade and alignment are controlled using inline cameras, a laser target system, and steering jacks. Excavated material is transported from the bore to the entry pit by either an auger or a slurry system. Where a slurry system is used, slurry tanks are normally provided on the surface to remove the spoil from the slurry water which is then recycled. The microtunnelling process is cyclical; after one pipe has been jacked into the bore, the jacks are retracted and another pipe is lowered into position in the entry shaft and the process repeated.



Key

1 power unit	5 hydraulic jacks
2 microtunnelling machine	6 crane or lifting equipment
3 jacking pipes	7 spoil skip
4 flush-fitting collars	8 spoil auger

Figure 26 — Trenchless replacement by pipe jacking — Schematic representation of replacement by microtunnelling

Table 15 — Features of replacement by pipe jacking

Features	Description
Relevant documents:	EN 12889, EN 14636-1, ISO 18672-1, ISO 25780
Materials new pipe:	GRP and PRC
Materials host pipe:	Not applicable (trenchless replacement off the existing line)
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— circular cross-section: — minimum size: 150 mm; — maximum size: 4 000 mm maximum length: 100 m.
Performance:	— hydraulic gradient can be restored; — fully structural rehabilitation is possible; — abrasion resistance depends on pipe material; — chemical resistance depends on pipe material.

Table 15 *(continued)*

Features	Description
Installation characteristics:	— surface working space a) Pipe jacking: Storage for pipe and auger sections, access for spoil, pipe and auger vehicles. b) Microtunnelling: Control room, power unit, slurry handling system, spoil handling system, pipe handling system, storage for pipe sections, access for pipe and spoil vehicles.
Installation equipment:	a) Pipe jacking: Auger and pipe jacking unit, power unit, pipe and auger handling system, spoil handling system. b) Microtunnelling: Microtunnelling machine, control room, power unit, slurry handling system, spoil handling system, pipe handling system.
Surface area:	a) Pipe jacking: Storage for pipe and auger sections, power unit, spoil handling system, access for spoil, pipe and auger vehicles. b) Microtunnelling: Storage for pipe sections, control room, power unit, slurry handling system, spoil handling system, access for pipe and spoil vehicles.
Excavation:	— at the insertion end: — to accommodate the jacking, pipe installation, and spoil removal systems. — at the receiving end: — to allow the removal of auger sections or the microtunnelling machine as applicable.

8 Information on design

8.1 General

It is the responsibility of the system owner to either choose and design the renovation or replacement system or nominate a competent person to do so. This document provides information for the processes of choice and design.

The steps generally to be followed in the renovation or replacement design process are the following:

a) assessment of the deficiencies of current performance of the existing pipeline;

b) identification of system requirements to achieve the desired functional performance;

c) determination of viable technique options, based on performance classifications and process-related factors;

d) specification of the optimum technique, the required amount and type of pipe material needed to secure the desired performance of the rehabilitated pipeline.

Steps a) to c) fall within the scope of this document and related information is given in Clauses 6 and 7.

8.2 Condition assessment

8.2.1 General

Apart from investigating deficiencies, the following basic information about the existing pipeline should be obtained:

a) the pipe material;

b) the pipe class (e.g. crushing strength, stiffness or pressure class);

c) the actual internal diameter or other non-circular section dimensions;

d) the joint type;

e) the fluid transported;

f) lengths of pipe between existing or potential access or inspection points;

g) the frequency of branches and service connections;

h) the type and location of other fittings;

i) location, angular change of alignment (vertical and horizontal) and approximate radius of bends;

j) the year of installation, if available;

k) the bedding and backfill of original construction, if available;

l) historical operating pressure and temperature regimes;

m) the service history including any previous failures and repairs;

n) potential arrangements for the maintenance of service during rehabilitation works.

NOTE 1 Some of these information can be ascertained from records and plans.

NOTE 2 For service activities relating to drinking water and waste water such as assessment of service to users and management of the utilities, see ISO 24510, ISO 24511 and ISO 24512.

8.2.2 Pipeline condition affecting functional performance

Methods for determining the condition of the existing pipeline differ in some respects for non-pressure and pressure applications and as a function of material, section size and shape.

In the case of non-pressure pipelines, the following information should, wherever possible, be obtained by visual inspection in the form of a high-definition colour closed-circuit television (CCTV) survey and/or profiling equipment and/or by man-entry, and should be recorded systematically such that the exact location of each feature, condition and defect is known and an assessment of its severity can be made:

a) geometric features, including:

   1) changes in diameter or, for non-circular pipelines, of section size and shape;

   2) degree of ovality or other relevant measure of section deformation;

   3) deviations of line and level;

   4) radial displacements such as stepped joints;

   5) axial displacements such as pulled joints;

b) hydraulic condition, such as:

   1) leakage;

   2) ponding;

   3) silting;

   4) obstacles to flow such as root growth, encrustations and/or protruding laterals;

c) structural defects, including:

   1) cracks/breaks;

2) collapses;

3) abrasion;

4) corrosion;

5) loss of section due to chemical attack.

NOTE As a result of the CCTV inspection, a more detailed examination can be carried out, requiring local excavations.

In the case of pressure pipelines, assessment of structural condition should be undertaken by non-destructive methods, which typically vary according to pipe material, and/or by extraction and evaluation of pipe samples. Assessment of geometric characteristics, where applicable, may be made by profiling or gauge pigging.

For water supply pipelines, the quantity of any leakage detected should be assessed where this is a factor in rehabilitation design.

8.2.3 Site conditions affecting design

The following site conditions should generally be determined:

a) the depth of cover to existing pipe;

b) the height of ground water table; including both mean long term and peak short term;

c) traffic or other surface loads;

d) any sources of possible future ground movement, including seismicity;

e) geotechnical information along the potential route, where relevant;

f) any evidence of deterioration of the surrounding soil, e.g. erosion voids and/or contamination;

g) Proximity of adjacent buried services and structures;

h) Environmental considerations such as water courses, aquifers, local ecology, etc.

Where the existing pipeline crosses contaminated ground, the resistance of the liner/replacement pipe and ancillary material to chemical attack or permeation by contaminants should be considered.

8.3 System functions

8.3.1 Renovation

Lining system functions generally include one or more of the following:

a) separation of the inner surface of the existing pipeline from the transported fluid to prevent mutual adverse reactions (for example, barrier function against corrosion of the existing pipeline by aggressive water);

b) sealing of the existing pipeline against infiltration of ground water or exfiltration of the transported fluid through leaking joints, cracks or holes;

c) stabilization or strengthening of the existing pipeline structure to extend its service life (e.g. where corrosion or chemical attack has resulted in loss of structural integrity or to allow for increases in operating pressure or other loads);

d) providing sufficient hydraulic capacity (e.g. by creating a smooth flow path);