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Plastics piping systems used for the rehabilitation of pipelines — Classification and overview of strategic, tactical and operational activities

Systèmes de canalisation en plastique destinés à la réhabilitation des réseaux enterrés — Classification et vue d'ensemble des activités stratégiques, tactiques et opérationnelles

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Foreword

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

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For an explanation 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 ISO/TC 138 *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 8, *Rehabilitation of pipeline systems,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 155, *Plastics piping systems and ducting systems,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 11295:2017), which has been technically revised.

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

— Title is renewed from "*Classification and information on design and applications of plastics piping systems used for renovation and replacement*" to "*Plastics piping systems used for the rehabilitation of pipelines — Classification and overview of strategic, tactical and operational activities*";

— Clause 5 has been added, describing the whole process of pipeline rehabilitation with references to the other clauses for further details;

— Clause 6 has been added, dealing with the strategic and tactical activities necessary to decide whether to rehabilitate; parts of the content of the former Clause 8 are included in this new clause;

— Former Clauses 5, 6 and 7 have been combined into Clause 7 with largely unchanged content;

— Clause 8 has been added, outlining the further tactical and operational steps needed to specify the rehabilitation project; parts of the content of the former Clauses 8 and 9 are included;

— Clause 9 still covers installation aspects but has been revised to include content on acceptance control.

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.

Introduction

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, they constitute a valuable asset to the network owner, requiring adequate management, including monitoring the performance of the pipeline system. For general guidelines and requirements on asset management, ISO 55000, ISO 55001 and ISO 55002 are applicable.

For the specific case of pipelines for water supply and wastewater collection, detailed information on the overall management of the networks is provided by ISO 24516-1 and ISO 24516-3.

In the case of loss of performance of a pipeline system, reactive measures initially focus on improving regular maintenance procedures, including cleaning. In case of deterioration or other serious defects, more stringent measures to rehabilitate the pipeline become necessary.

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

This document provides information on the design process when considering rehabilitation of an existing pipeline, in order of sequence:

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

b) determination of viable options, based on performance criteria and process-related factors;

c) specification of the selected type of technique and the required pipe material;

d) the installation;

e) testing the performance.

The techniques used for the renovation and trenchless replacement of existing pipelines are classified in technique families and the typical characteristics of each are described in general terms.

Plastics piping systems used for the rehabilitation of pipelines — Classification and overview of strategic, tactical and operational activities

1 Scope

This document specifies the steps of the overall process of pipeline rehabilitation, comprising:

— information on strategic and tactical activities:

a) investigation and condition assessment of the existing pipeline;

b) pipeline rehabilitation planning.

— information on and requirements for operational activities:

c) project specification;

d) applications of techniques;

e) documentation of the design and application process.

Definitions and classification of families of renovation and trenchless replacement techniques are provided, and their respective features described. Areas of application covered include underground drainage and sewerage networks and underground water and gas supply networks.

The following aspects are not covered by the scope of this document:

— new construction provided as network extensions;

— calculation methods to determine, for each viable technique, the characteristics of lining or replacement pipe material needed to secure the desired performance of the rehabilitated pipeline;

— techniques providing non-structural pressure pipe liners;

— techniques for local repair.

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

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 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 General terms

3.1.1
assessment
process, or result of this process, comparing a specified subject matter to relevant references

3.1.2
design working life
assumed period for which a structure or part of it is to be used for its intended purpose with anticipated *repair* (3.1.7) and *maintenance* (3.1.11) but without *renovation* (3.1.6) or *replacement* (3.1.8) being necessary

3.1.3
hazard
condition of water, or biological, chemical, physical or radiological agent with the potential to cause harm to public health

Note 1 to entry: Condition includes quantity.

[SOURCE: EN 15975-1:2011+A1:2015, 2.6; modified]

3.1.4
pipeline system
interconnecting pipe network for the conveyance of fluids

[SOURCE: ISO 11298-1:2018, 3.1.1]

3.1.5
rehabilitation
measures for restoring or upgrading the performance of existing *pipeline systems* (3.1.4), including *renovation* (3.1.6), *repair* (3.1.7) and *replacement* (3.1.8)

3.1.6
renovation
work incorporating all or part of the original fabric of the pipeline, by means of which its current performance is improved

3.1.7
repair
rectification of local damage

3.1.8
replacement
construction of a new pipeline, on or off the line of an existing pipeline, where the function of the new *pipeline system* (3.1.4) incorporates that of the old

3.1.9
network extension
new construction off the line of a pipeline or a network with the aim to expand the total capacity of the network

3.1.10
trenchless replacement
replacement (3.1.8) without opening trenches other than small excavations to provide access for the particular technique

3.1.11
maintenance
routine work undertaken to ensure the continuing performance of a *pipeline system* (3.1.4)

3.1.12
independent pressure pipe liner
liner (3.2.3) capable on its own of resisting without failure all applicable internal loads throughout its design life

3.1.13
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

3.1.14
fully structural renovation
use of an *independent pressure pipe liner* (3.1.12) which is capable of resisting all external loads irrespective of the condition of the existing pipeline

3.1.15
semi-structural renovation
use of an *interactive pressure pipe liner* (3.1.13) which is capable of long-term hole and gap spanning at operational pressure

3.1.16
non-structural renovation
use of an *interactive pressure pipe liner* (3.1.13) which is not capable of long-term hole and gap spanning at operational pressure

3.1.17
flow diversion
temporary isolation of the section of pipeline to be rehabilitated by the use of a temporary bypass or other means

3.2 Terms related to techniques

3.2.1
technique family
grouping of *renovation* (3.1.6) or *trenchless replacement* (3.1.10) techniques which are considered to have common characteristics for standardization purposes

3.2.2
lining pipe
pipe inserted for *renovation* (3.1.6) 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* (3.1.6)

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 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 the circumference

3.2.15
pipe bursting
on-the-line *replacement* (3.1.8) 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* (3.1.8) 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 *trenchless replacement* (3.1.10) 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 *trenchless replacement* (3.1.10) method in which pipes are pulled in behind a pneumatic powered soil displacement hammer

3.2.21
pipe jacking
off-the-line *trenchless replacement* (3.1.10) 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 Terms related to services conditions

3.3.1
internal pressure resistance
ability to withstand internal fluid pressurization

3.3.2
allowable operating pressure
PFA
maximum hydrostatic pressure that a component is capable of withstanding continuously in service.

Note 1 to entry: It is expressed in bars[1)].

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

DN nominal diameter

1) 1 bar =0,1 MPa = 0,1 N/mm^2 = 10^5 N/m^2.

HDD	horizontal directional drilling
EP	epoxy resin
GRP	glass-reinforced thermosetting plastics
PE	polyethylene
PFA	allowable operating pressure
PP	polypropylene
PRC	polyester resin concrete
PUR	polyurethane
PVC-U	unplasticized poly(vinyl chloride)
RFC	resin fibre composite
UP	unsaturated polyester resin
VE	vinyl ester resin

5 Pipeline rehabilitation process

The overall process of pipeline rehabilitation involves several sequential steps, for which this document provides information and requirements as follows:

1) investigation of functional performance of the existing pipeline 2) condition assessment of performance against set requirements 3) measures to control risks / pipeline rehabilitation	Clause 6
4) pre-selection of suitable types of rehabilitation techniques	Clause 7
5) project specification 6) selection of technique / installer	Clause 8
7) application of rehabilitation technique 8) acceptance control	Clause 9
9) documentation of the rehabilitation process	9.7

A substantial part of this document (Clause 7) is dedicated to the classification of families of techniques for pipeline rehabilitation, covering both renovation and trenchless replacement. Key features, including typical product characteristics, areas of application and process related factors are described for each technique family.

NOTE Guidance on the whole process of integrated management of drains and sewers is presented in EN 752.

6 Investigation and condition assessment of the existing pipeline

6.1 Performance criteria

6.1.1 General

For every pipeline system certain objectives apply, depending on their intended functionality.

These are the basis for the performance requirements of a pipeline system. The pipeline system objectives that impact on the performance requirements of the individual pipeline, shall be identified.

For drinking water distribution networks and wastewater collection networks, detailed guidance and requirements are provided by ISO 24516-1 and ISO 24516-3 respectively. The items detailed below specifically relate to the rehabilitation process of the pipeline systems in these networks, as well as in gas supply networks.

Pipeline system objectives include at least the following:

— health and safety;

— environmental protection;

— sustainable operation.

Health and safety encompasses (depending on the function of the pipeline):

— provision of access to safe and good-quality drinking water;

— preventing spread of disease by safe disposal of wastewater;

— meeting user's needs and expectations;

— minimizing occupational health and safety risks;

— maintaining pipeline system integrity.

Environmental protection includes:

— preventing pollution and minimizing generation of pollutants;

— minimizing energy consumption;

— avoiding nuisance in construction, operation and maintenance.

Sustainable operation includes:

— providing service over many years: economic, social, environmental;

— monitoring the quality of water (sampling, surveillance, maintenance);

— minimizing mains failures and leakages.

The objectives shall be transformed to performance requirements and the resulting design criteria that ensure functionality of the pipeline system, such as: structural integrity, design working life, leak tightness, prevention of pollution, sustainability and maintenance of flow.

Objectives can be split into the following categories:

— hydraulic requirements;

— structural requirements;

— environmental requirements;

— operational requirements.

NOTE 1 In ISO 24512 'performance requirements' are recommended to be clearly specified in objective, verifiable 'Performance Indicators (PIs)', allowing for a clear comparison with the targeted objectives.

NOTE 2 In EN 752, 'performance requirements' are for the status quo. When any predicted changes in time are taken into account, they become 'design criteria'.

6.1.2 Hydraulic requirements

The following hydraulic requirements shall be considered:

a) sufficient capacity, allowing for foreseeable increases in flow over the design working life of the pipeline system;

b) ensuring operation of the pipeline system to be safe and economically efficient;

c) leak tightness in accordance with national or local testing requirements;

d) in the case of water supply pipelines, national or local regulations can additionally require:

— safeguarding of water quality;

— sufficient pressure, flow rate and continuity of supply;

— prevention of back flow (via valves and wash outs);

— minimization of stagnation to avoid possible deterioration of water quality;

— requirements for firefighting (hydrants) to follow requirements of national legislation;

— prevention of contamination at pumping stations.

e) in the case of non-pressure drainage and sewerage networks,

— national or local regulations or the relevant authority can specify requirements for limitation of surcharge or flooding.

6.1.3 Structural requirements

The following shall apply:

a) structural integrity over the design working life of the pipeline system;

The pipeline system shall be able to withstand the loads without defects which can:

— lead to risk of loss of structural integrity;

— impair the function of the pipeline system.

6.1.4 Environmental requirement

The following shall apply:

a) protection of groundwater;

b) sustainable use of products and potential re-use through recycling;

c) minimization of the use of energy over the design working life of the pipeline system;

d) prevention of odours and toxic, explosive and corrosive gases.

6.1.5 Operational requirements

The following shall apply:

a) trouble-free operation of the pipeline system, without interruptions of service;

b) minimization of the risk of failures: collapses (non-pressure pipelines) or bursts (pressure pipelines);

c) maintenance to be carried out safely and without risks to the health of personnel;

d) adequate access and working space;

e) prevention of noise and vibration;

f) not endangering adjacent structures and utility services.

6.2 Investigation of performance

6.2.1 General

Prior to the actual investigation, the following basic information about the existing pipeline shall be collected:

a) location;

b) pipe material;

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

d) wall thickness (especially in the case of pressure pipelines where interactive lining is considered);

e) fluid transported;

f) accessibility and section lengths between access points;

g) frequency and location of any lateral connections, branches and/or valves;

h) depth of cover;

i) height of ground water table (both mean long-term and peak short-term);

j) flow quantity;

k) failure and repair records;

l) historical operating pressure regimes;

m) traffic or other surface loads;

n) proximity of adjacent buried services and structures.

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

If available, the following additional information shall be acquired additionally:

— year of installation;

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

— joint type;

— bedding and backfill of the original construction.

Methods for determining the condition of the existing pipeline affecting functional performance 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 initial investigation shall be carried out by visual inspection in the form of a CCTV survey and/or profiling equipment and/or by person-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.

In the case of pressure pipelines, the initial investigation shall be carried out by non-flow-interrupting techniques, such as via sonar/acoustic sensors, tracer gas leak detection and ground penetrating radar measurements, in a second step possibly to be followed by a CCTV survey and testing on leak tightness (see also 9.5.3.2).

In both cases, further investigation shall be carried out by checking exposed pipe sections and/or by extraction and evaluation of pipe samples.

Where a substantial pipeline network shall be investigated, priorities shall be assigned, using the already available information. Those pipelines likely to have the most serious problems, or those where the cost of investigation is best justified, shall be investigated first.

Prior to inspection, in particular in the case of non-pressure drainage and sewerage networks, the pipelines should be cleaned thoroughly (removing sediments, etc.).

NOTE 2 Further information on the investigation, assessment and other service activities relating to drinking water and waste water and management of these utilities, is given in ISO 24510, ISO 24511, ISO 24512, ISO 24516-1 and ISO 24516-3 and additionally, just for drainage and sewerage networks by EN 752 and EN 13508-1. Further information on the inspection and leak survey of gas pipeline systems is provided by EN 12007-1 and EN 12007-4.

6.2.2 Hydraulic investigation

The following aspects of hydraulic condition of the pipeline shall be investigated:

— with non-pressure lines:

a) infiltration (groundwater) and exfiltration;

b) obstacles to flow such as ponding, sedimentation, encrustations, protruding laterals and root growth;

— and with pressure lines:

c) leakage; the quantity of leakage shall be assessed;

d) obstacles to flow such as sedimentation, scaling, protruding service lines;

e) situations and consequences where gases can be trapped in pipes for liquids or where water can be trapped in pipes for gas;

f) potential for surge pressures (or vacuum) to arise in foreseeable operational circumstances.

NOTE Investigation techniques include pressure testing, flow measurement, water level measurement and hydraulic calculations. Furthermore, smoke and/or acoustic testing and tracer measurements are applied. In particular for water mains, acoustic testing methods are used to detect any leaks.

6.2.3 Structural investigation

The following aspects of the structural condition of the pipeline shall be investigated:

a) interior geometric features:
   - changes in diameter (for non-circular pipelines, of section size and shape);
   - degree of ovality or other relevant measure of section deformation;
   - angular change of alignment (vertical and horizontal);
   - approximate radius of any bends;
   - radial and axial displacements such as stepped and pulled joints.

b) structural defects, including:
   - cracks/breaks and collapses;

— abrasion and corrosion;

— loss of section due to chemical attack.

c) pipe surround aspects, including:

— any sources of possible future ground movement, including seismic events;

— geotechnical information along the potential route, where relevant;

— any evidence of deterioration of the surrounding soil, e.g. contamination.

NOTE Detailed information on the classification of CCTV inspection results of drainage and sewerage networks is provided by EN 13508-2. In EN 13508-2, a coding system for the description of the internal condition of the pipeline and the manhole/inspection chamber is specified. Colour photographs showing examples of some observations are included to illustrate the use of the coding systems.

The extent of the structural investigation (either on the complete pipeline system or more selectively) should take into account the age and location of the pipeline system and the possible effect of any deficiencies on the environment, including other utility services and buildings.

6.2.4 Environmental investigation

Environmentally, adjacent water courses, aquifers, local ecology, etc. shall be investigated.

6.2.5 Operational investigation

The operational performance of the pipeline system shall be assessed from:

a) records of operational incidents or failures;

b) customer complaints, in the case of water supply, concerning pressure and quality (clarity, colour, taste and odour).

Additionally, with regard to possible potential arrangements for rehabilitation works, the following aspects shall be investigated:

c) access to the site and the pipeline;

d) temporary traffic diversion arrangements;

e) maintenance of service during rehabilitation works.

6.3 Condition assessment

At this stage in the process, the performance condition of the pipeline (as determined according to 6.2) shall be assessed against the set performance requirements (as prescribed in 6.1).

Deficiencies in hydraulic, structural and operational performance shall be identified.

The causes of the deficiencies, in particular of the structural deficiencies, shall be identified to assist in preventing them from re-occurring.

The possible consequences of deficiencies shall be considered, including the following:

a) effect on public health, including continuity of supply with water supply pipelines;

b) endangering safety;

c) environmental damage, in particular with drainage and sewerage networks:

— pollution, both of surface water (following flooding) and ground water (following exfiltration);

— subsidence (following pipe collapses and soil ingress); can cause damage to the road surface, other utility services, buildings or other structures;

— social disruption, caused by road closures (following pipe failures), or e.g. excessive odours.

d) financial costs:

— direct costs, e.g. cost of rehabilitation or increased energy costs due to infiltration;

— indirect costs, e.g. damage to buildings and contents, compensation for loss of service.

6.4 Risk analysis

The risk of each deficiency, typically called 'hazard' in the case of water supply lines, shall be analysed, taking into account the likelihood/probability of a negative effect occurring and its consequence.

The aim shall be to make distinction between different sorts of risks (significant to less significant) and thus to provide tools for prioritization for further pipeline management actions. Risk can be expressed as a product of likelihood and consequence:

$$a = b \times c$$

where

a is risk;

b is likelihood;

c is consequence.

NOTE 1 As proposed in WHO WSP[59], the likelihood of occurrence is indicated by 'certain', 'possible' and 'rare', for example, and the consequence is indicated by 'catastrophic', 'major' and 'insignificant', for example.

NOTE 2 Further detailed information on risk analysis is provided for non-pressure drainage and sewerage networks in EN 13508-1, EN 14654-1, -2 & -4, for water supply pipelines in EN 15975-2, WHO WSP[59], WIS 4-01-04[60] and for gas supply pipelines in EN 12007-1.

6.5 Control measures

The result of the assessment and risk analysis shall be worked up into adjustment of operational procedures and, if applicable, a plan for the rehabilitation of the pipeline.

Operational measures are generally short-term and include:

— cleaning to improve efficiency and chlorination (water supply pipelines);

— pump station operation/pressure management.

Pipeline rehabilitation measures are generally medium-term to long-term and include:

— selections of type of pipeline rehabilitation;

— design of the new pipe;

— allocating sufficient funding, possibly involving multi-year work plans.

Selecting the optimal measure of control to prevent any risks from occurring is complex and involves both technical and financial considerations.

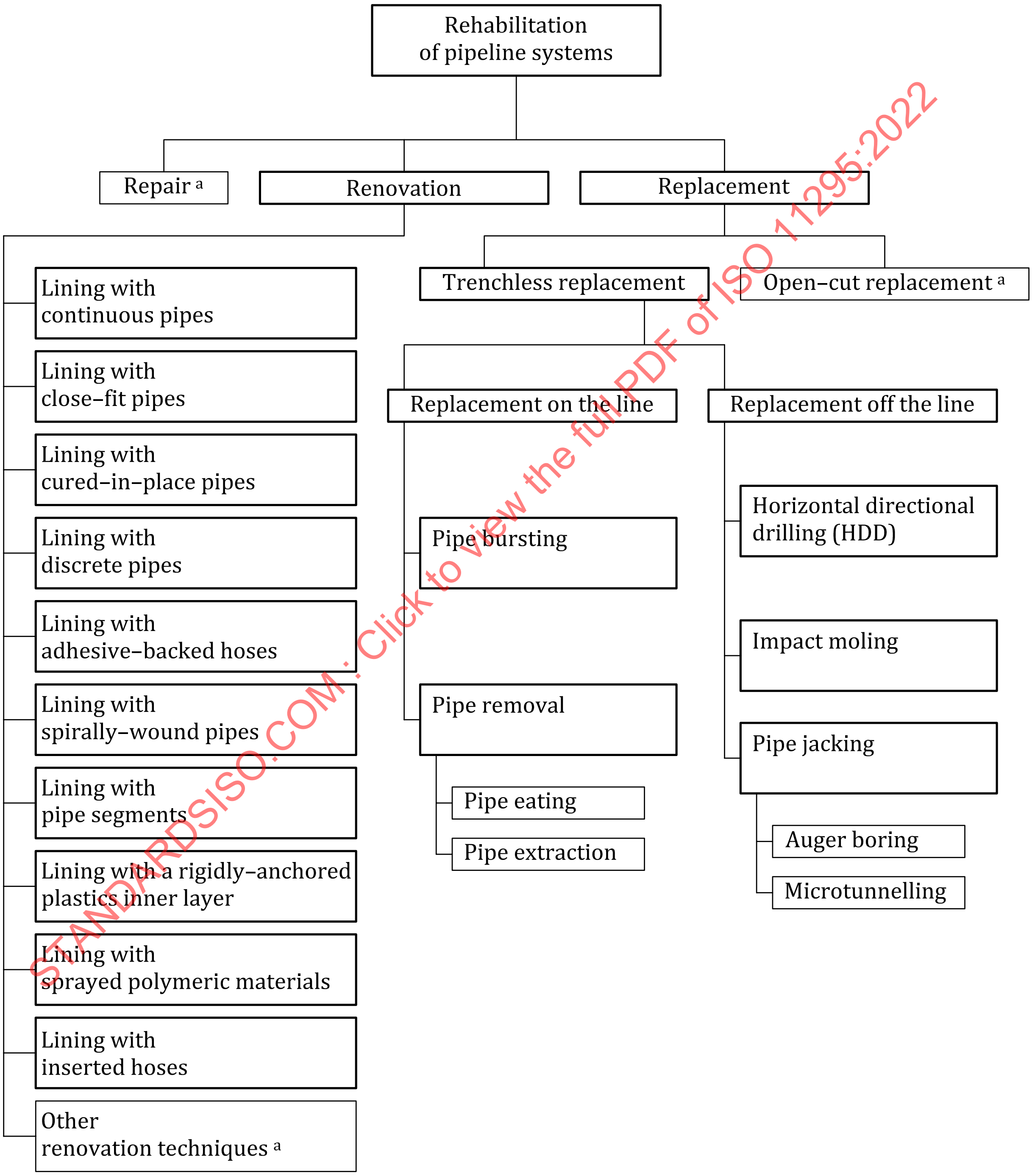
Within the scope of this document, pipeline rehabilitation options are limited to renovation and trenchless replacement techniques. Open-cut replacement and repair are excluded. See Clause 7.

For further information on pipeline rehabilitation design, see Clause 8.

7 Classification and characteristics of rehabilitation techniques

7.1 Overview

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



Key

a Outside the scope of this document.

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

7.2 Classification of renovation techniques

7.2.1 General

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);

e) providing earthquake protection, in particular, by preventing leakage and consequential losses that might otherwise result from sudden and severe damage to the existing pipeline network.

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 7.2.2 to 7.2.11, where the different renovation technique families are specified and their respective features including materials, application, as well as geometric performance and installation characteristics are described.

NOTE 1 The pipe materials listed in 7.2.2 to 7.2.11 reflect the state-of-the-art in the technique families at the time of publication of this document. Not all technique families/material-combinations are covered by a product standard. The Bibliography gives relevant available documents.

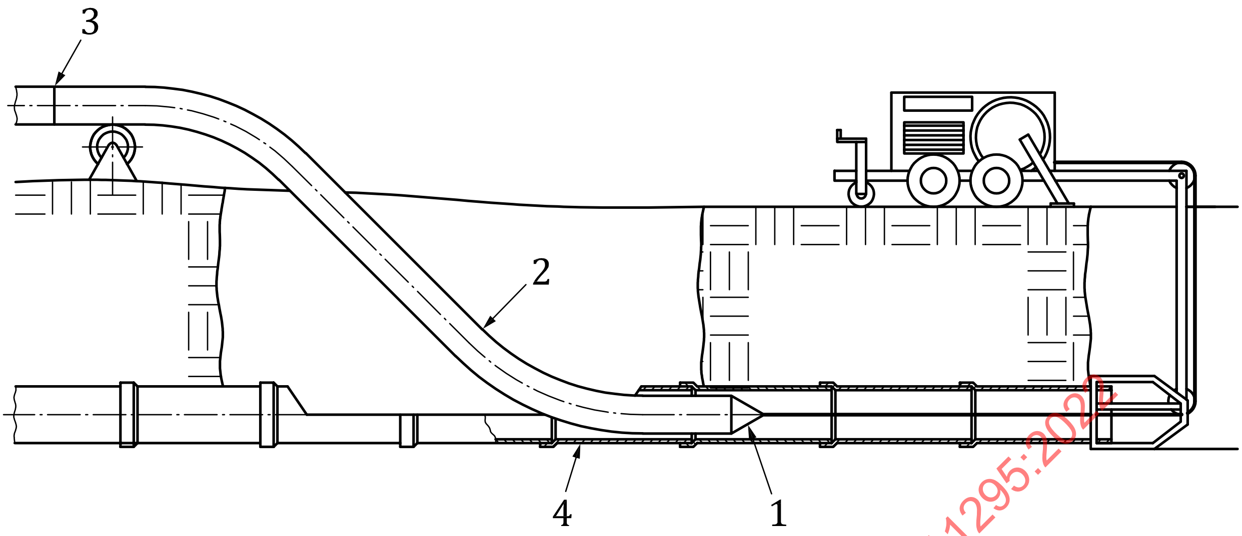
NOTE 2 The application areas covered by existing product standards include underground drainage and sewerage networks and underground water and gas supply networks.

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

7.2.2 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, ISO 23818-1
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; — fully-structural renovation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.

Table 1 *(continued)*

Feature	Description
Installation characteristics:	— pipes manufactured or prior assembled into the continuous length required; — insertion possible by pushing and/or pulling; — surface working space: storage of the whole insertion length required on surface: a) small diameters (typically ≤ 180 mm) can be supplied on coils, small space; b) larger diameters: supplied in straight lengths; — access to the existing pipeline: generally requires local excavation; — technique does not rely on adhesion to host pipe; — flow diversion is typically required for installation; — the annular space can be grouted, for example in non-pressure applications, to fix line and level and/or prevent subsequent movement; — live insertion is possible (but excluding drinking water applications for hygiene reasons); — 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.

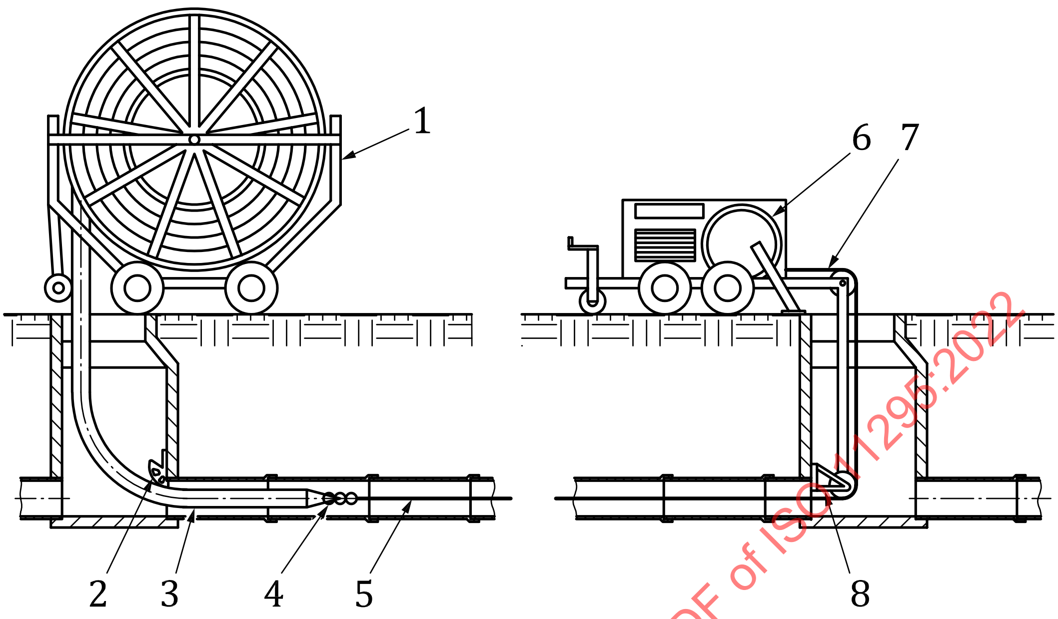
7.2.3 Lining with close-fit pipes

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 simultaneously inserted.

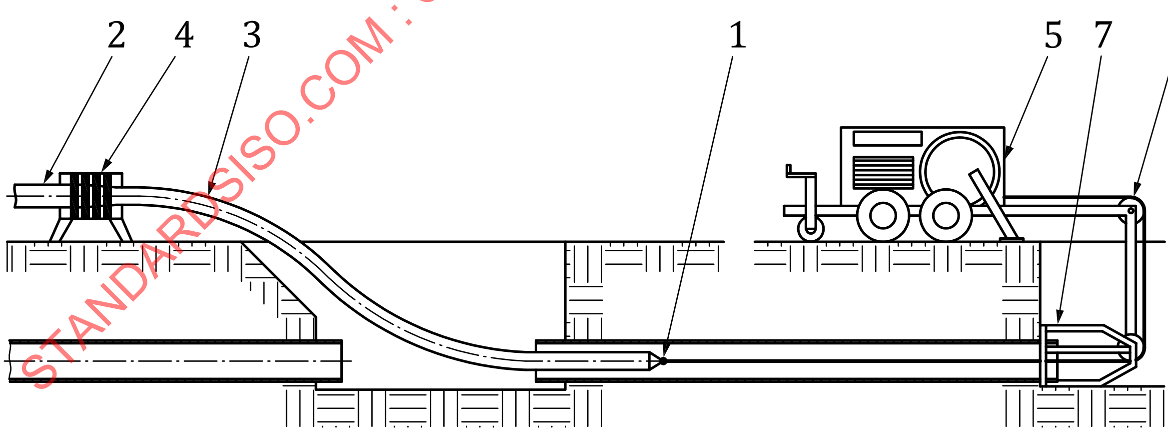


Key

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, ISO 23818-1, ISO 23818-3
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; — fully-structural renovation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.
Installation characteristics:	— 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; — 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); — access: typically through manhole for Method A, requires local excavation for Method B; — technique does not rely on adhesion to host pipe; — flow diversion is required; — grouting not applicable; — reconnection of laterals: a) gravity pipelines: possible from inside (re-opening and tight connection); b) 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]; — a compressor and a steam generator (where applicable), for lining pipe reversion; — jointing equipment appropriate to 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)*

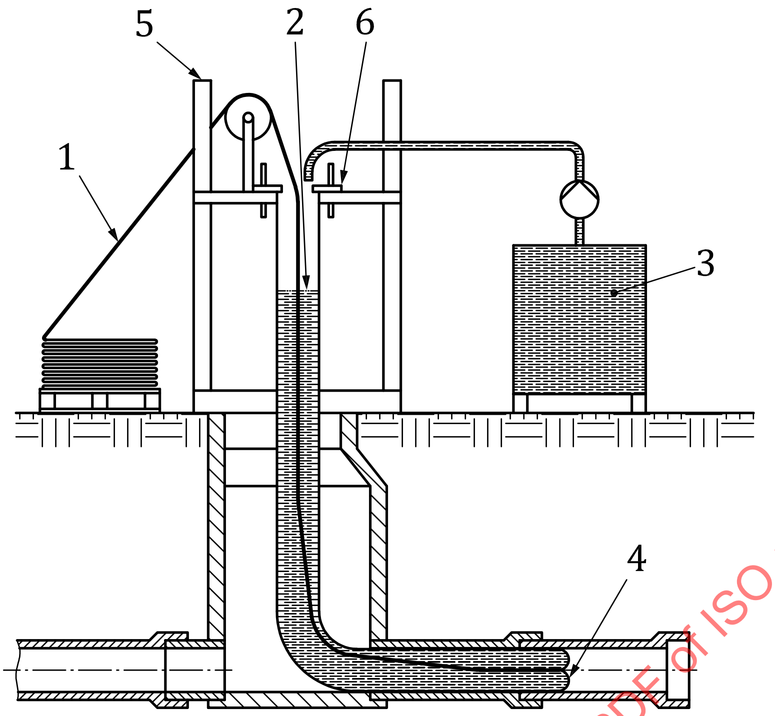
Feature	Description
Surface area:	— for the lining pipe string (or coil trailer for smaller diameters and/or folded pipe) at the insertion end; — for reducing or folding equipment at the insertion end where reduction or folding is carried out simultaneously with insertion; — for a winch at the receiving 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.	

7.2.4 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 A1), Figure 6 (Method A2), Figure 7 (Method B) and Table 3].

a) Method A: installation by inversion, either using a scaffold water tower, or an air pressure vessel.

b) Method B: installation by winching.



Key

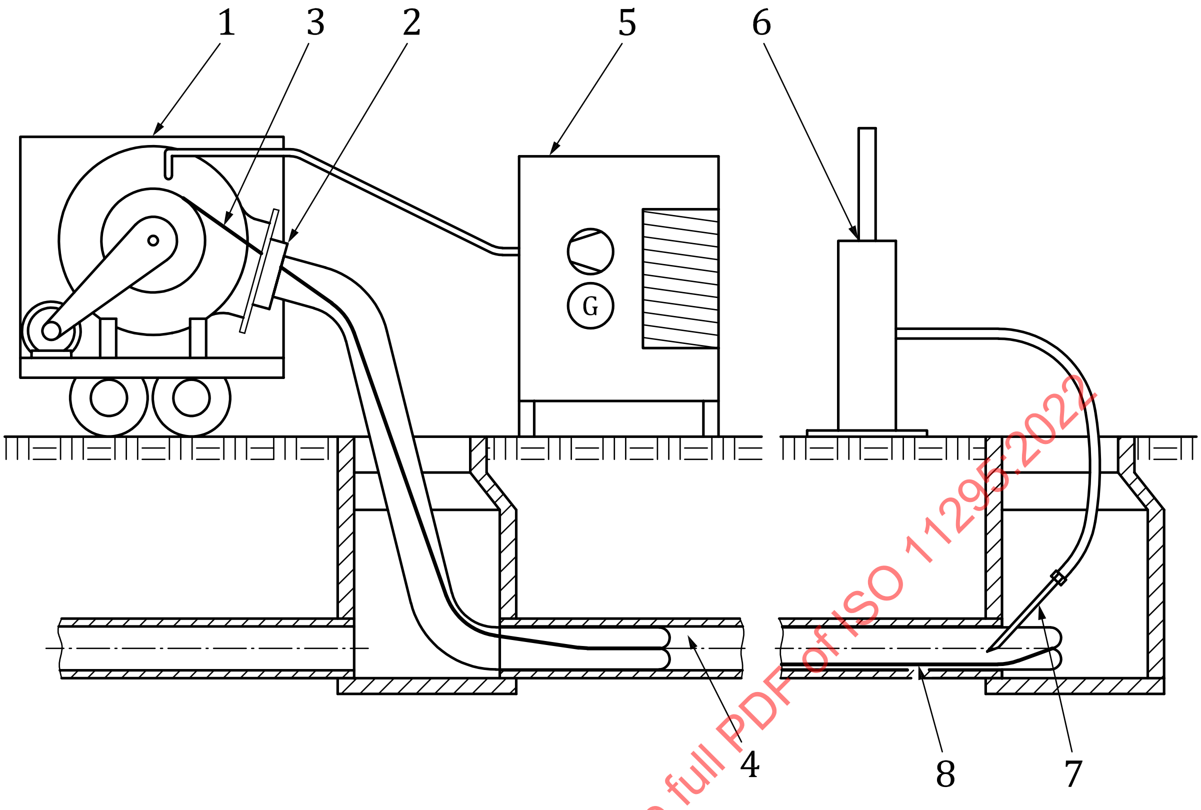
1	lining tube	4	inversion face
2	applied water head for inversion	5	scaffold tower
3	water reservoir	6	clamping flange or ring

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

NOTE 2 Head of water for inversion can also be generated with aid of a pressure vessel.

NOTE 3 For CIPP the lining pipe is defined as lining tube. See ISO 11296-4:2018, 3.1.11.

Figure 5 — Lining with cured-in-place pipes — Schematic representation of installation by inversion (Method A1), showing use of scaffold tower and water

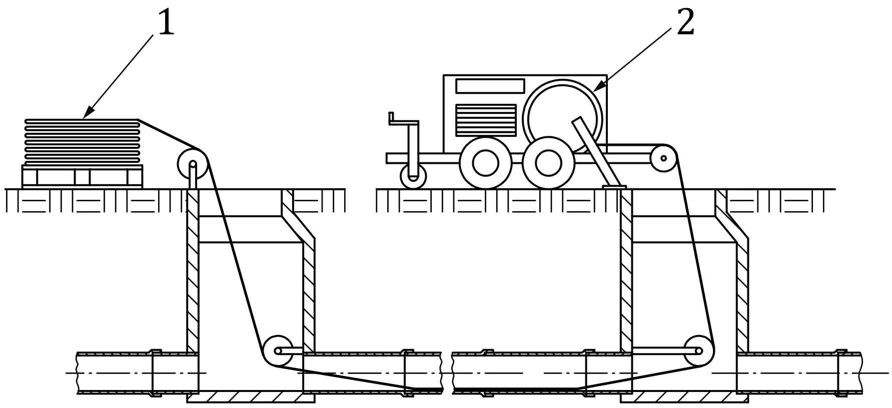


Key

1 inversion unit
2 clamping flange
3 impregnated lining pipe
4 inversion face
5 heating unit (steam boiler, compressor, generator)
6 steam exhaust
7 steam lance
8 retaining belt

NOTE 4 Equipment for commonly-applied steam curing shown. Ambient curing also possible.

Figure 6 — Lining with cured-in-place pipes — Schematic representation of installation by inversion (Method A2), showing use of air pressure vessel



Key

1 impregnated lining pipe

2 winch

NOTE 5 The equipment used to inflate and cure lining pipe once winched in place (e.g. air compressor and steam generator or UV light train) is not shown.

Figure 7 — 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, ISO 11298-4, ISO 23818-2
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; in the case of drinking water, CIPP specific national or local regulations can apply.
Geometric characteristics:	— circular and non-circular cross-section; — minimum size: 50 mm; — maximum size: 2 800 mm; — maximum length: Method A: 1 000 m, Method B: 500 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; — fully-structural renovation is possible; — abrasion resistance depends on liner materials and wall structure; — chemical resistance depends on liner materials and resin type.

Table 3 *(continued)*

Feature	Description
Installation characteristics:	— insertion of the lining tube, prior to curing, can be achieved by: a) inverting into position with pressure only (water or air); or b) winching into place and then inflating; c) combinations of Methods A and B are also possible; — curing process can be initiated or accelerated by either: a) heat (hot water, steam); b) UV or other electromagnetic wavelengths; or c) ambient temperature; — surface working space: generally minimal, varies with technique; — access: entry through existing manhole or small excavation possible; — structural effect does not rely on adhesion to host pipe; — flow diversion required; — re-opening of laterals from inside is possible; — reconnection of laterals: a) gravity pipelines: possible from inside (re-opening and tight connection); b) in pressure applications: generally requires excavation.
Installation equipment:	— lining pipe delivery unit, including conveyor system, if applicable; — site impregnation unit, if applicable; — for inverted-in-place pipeline systems: water column or air compressor; — for winched-in-place pipeline systems: winch and water boiler or steam generator for heat curing, or equipment including power supply for UV or other electromagnetic wavelengths.
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.

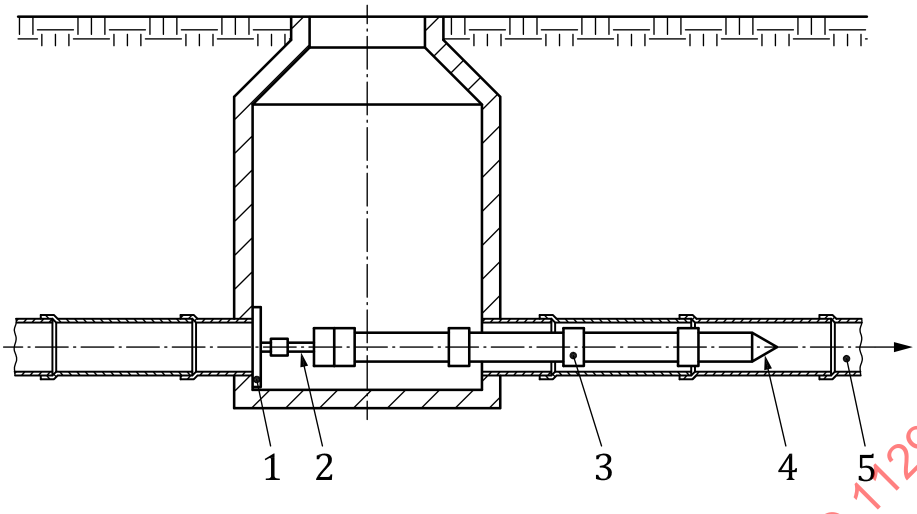
7.2.5 Lining with discrete pipes

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 8 (Method A), Figure 9 (Method B), Figure 10 (Method C) and Table 4].

a) Method A: installation by pushing.

b) Method B: installation by pulling.

c) Method C: installation by individual pipe placement.

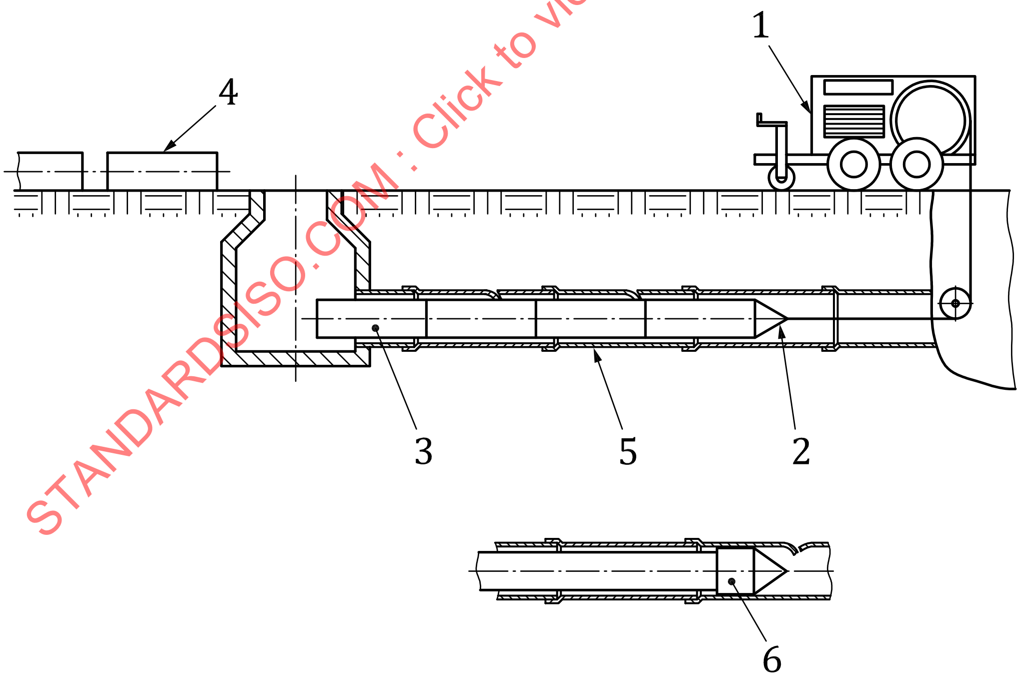


Key

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.

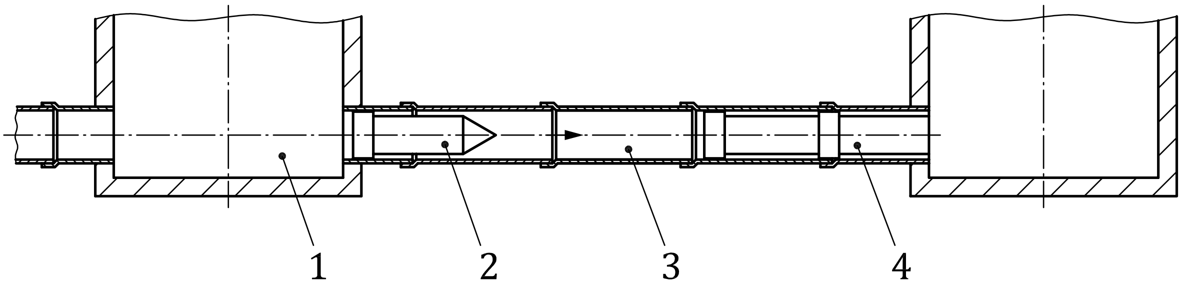
Figure 8 — Lining with discrete pipes — Schematic representation of installation by pushing (Method A)



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 9 — 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 10 — 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[a], ISO 10639[a] and ISO 16611, ISO 23856 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:	
	Method A and B:	150 m;
	Method C:	no limit intrinsic to technique.
	— 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 person-entry pipes; — fully-structural renovation is possible; — abrasion resistance depends on liner material; — chemical resistance depends on liner material.	

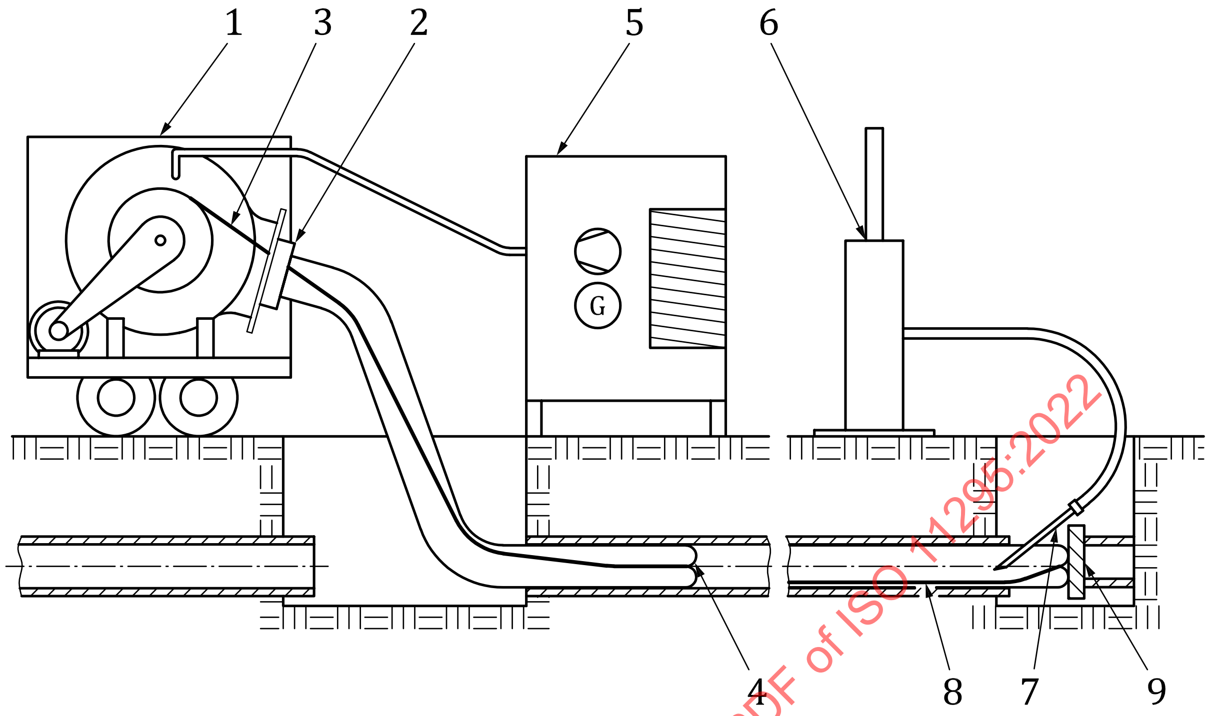
[a] ISO 10467:2018 and ISO 10639:2017 have been revised by ISO 23856:2021.

Table 4 *(continued)*

Feature	Description
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 person-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 person-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; — person-entry access needed at receiving end.
[a] ISO 10467:2018 and ISO 10639:2017 have been revised by ISO 23856:2021.	

7.2.6 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 11 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 11 — 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; — fully-structural renovation 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.

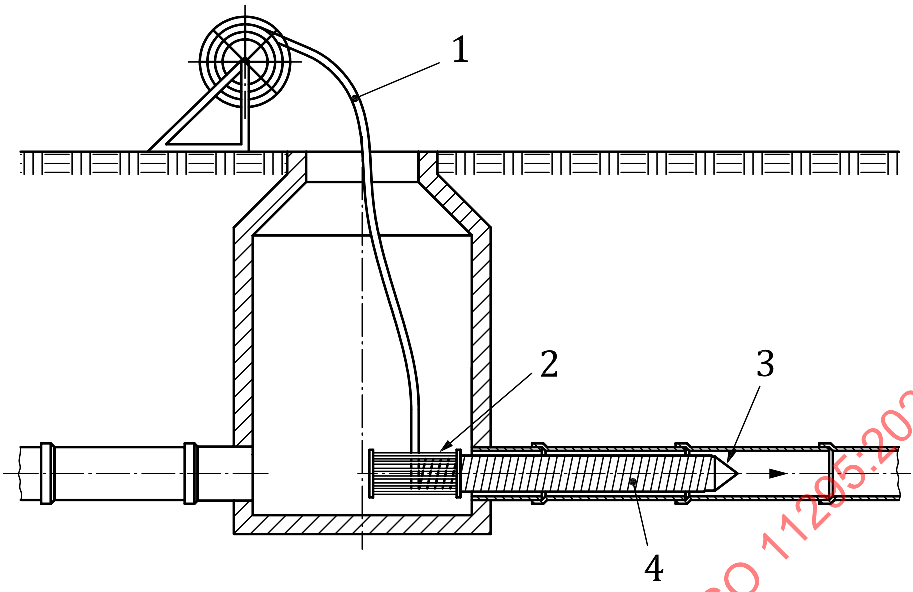
7.2.7 Lining with spirally-wound pipes

Lining is carried out with a profiled strip, spirally wound to form a continuous pipe after installation [see Figure 12 (Method A1), Figure 13 (Method A2), Figure 14 (Method B) and Table 6].

a) Method A1: installation by fixed diameter winding from the manhole.

b) Method A2: installation by expanded diameter winding from the manhole.

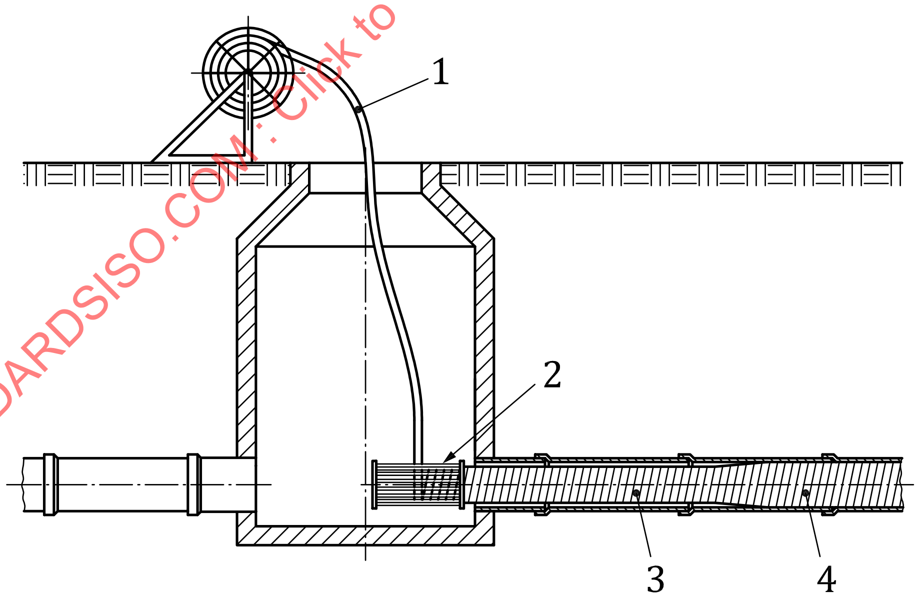
c) Method B: installation by winding of liner from pipe-traversing winding machine.



Key

1 plastics strip to be spirally wound
2 winding machine in the manhole
3 guidance head (where applicable)
4 spirally-wound lining pipe

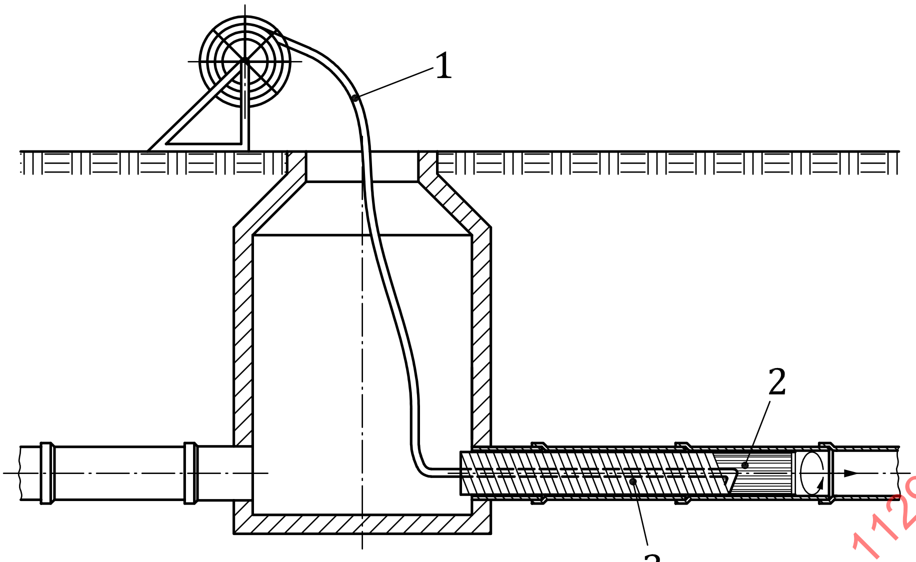
Figure 12 — Lining with spirally-wound pipes — Schematic representation of fixed diameter winding from the manhole (Method A1)



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 13 — 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 14 — 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

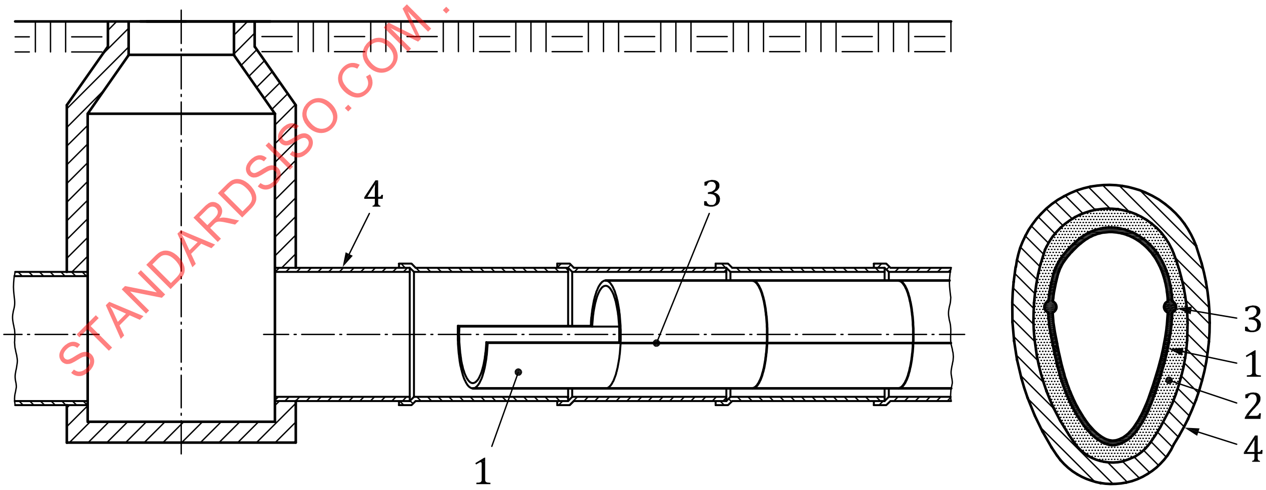
Feature	Description
Relevant documents:	ISO 11296-7, ISO 23818-1, ISO 23818-3
Materials:	PVC-U, PE, optional steel reinforcement
Applications:	— non-pressure; — applicable for manholes.
Geometric characteristics:	— Method A circular cross-section only; Method B adaptable also to non-circular sections; — 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.
[a] Larger sizes are possible with steel reinforcement.	

Table 6 *(continued)*

Feature	Description
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-person-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.	

7.2.8 Lining with pipe segments

Lining carried out with prefabricated segments bonded to the existing pipe (see Figure 15 and Table 7), which have longitudinal joints.



Key

1 lining pipe segments
2 grout
3 longitudinal joints
4 existing pipe

Figure 15 — Schematic representation of lining with pipe segments

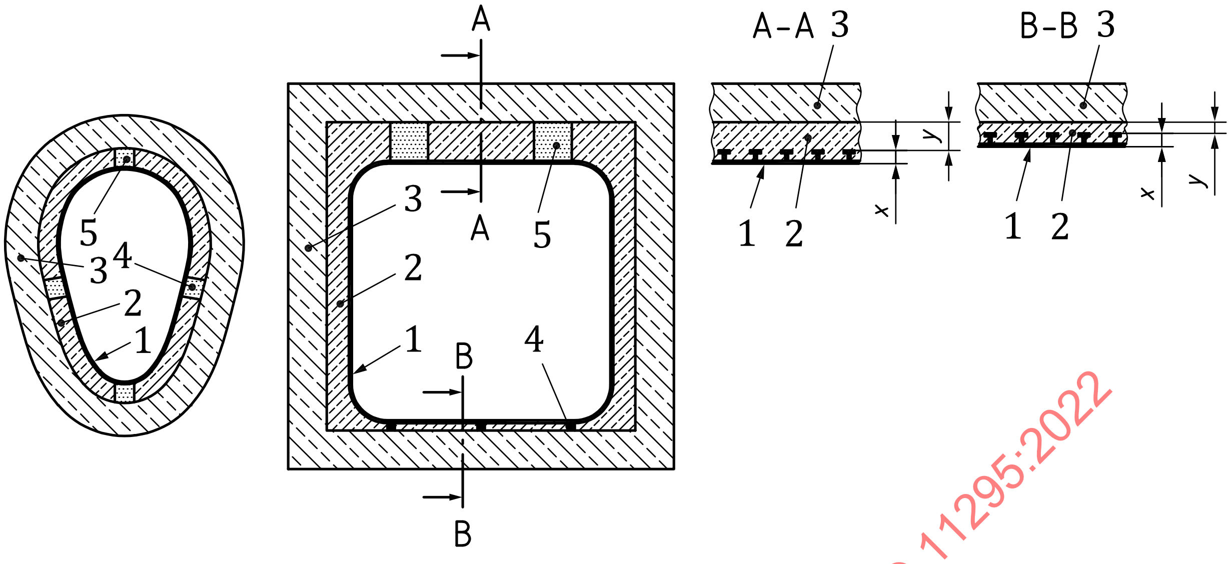
NOTE Partial lining, not covering the whole circumference of the pipeline, is outside the scope of this document.

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: person-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.
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.

7.2.9 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 16 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 16 — Typical wall construction of a lining system with plastics inner layer rigidly anchored in structural cementitious grout

Different types of internal plastics layers 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 7.2.5, as well as profiled plastics strips formed into a pipe by spirally winding according to 7.2.7 or by other means and pipe segments of plastics materials according to 7.2.8, where structural performance depends on permanent anchorage of the plastics components 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 (to be replaced by ISO 11296-9[a])
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[b]; — maximum length: 200 m; — bends can be accommodated.

[a] Under preparation. Stage at the time of publication ISO/FDIS 11296-9:2022.

[b] Sizes up to 5 000 mm are possible with certain specialized techniques and materials.

Table 8 *(continued)*

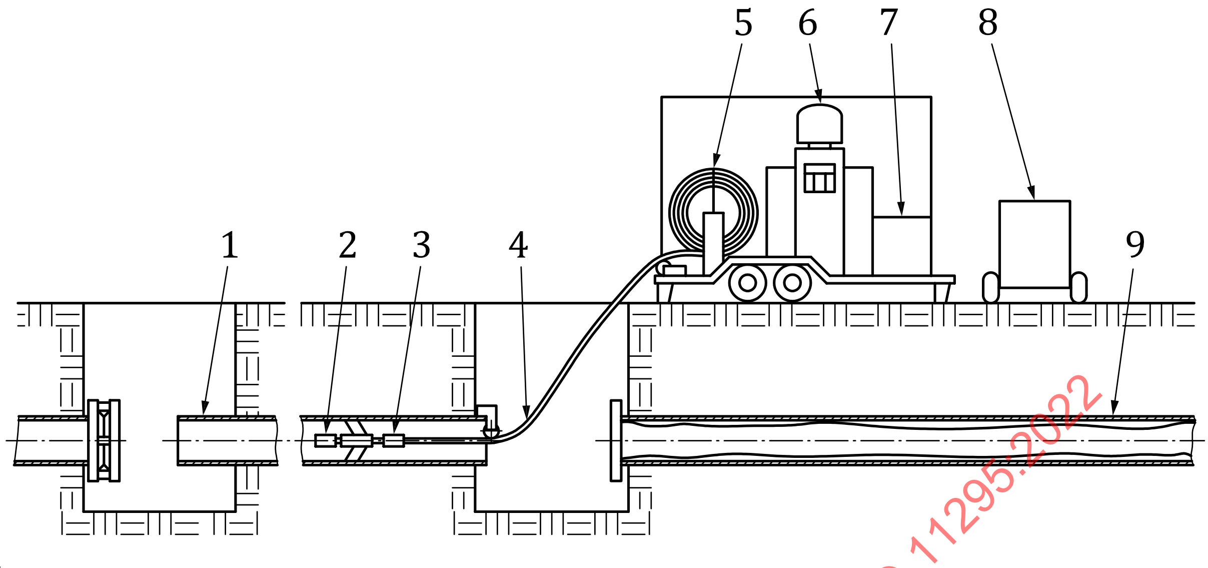
Feature	Description
Performance:	— reduction in capacity dependent on annular space and ratio of diameter to overall profile height; — uniform gradient can generally not be restored; — structural renovation is possible (depending on the strength of the grout); — inner plastics layer material determines 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] Under preparation. Stage at the time of publication ISO/FDIS 11296-9:2022.

[b] Sizes up to 5 000 mm are possible with certain specialized techniques and materials.

7.2.10 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 17 and Table 9). This technique family relies on the existing pipeline for its structural performance.



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 17 — Lining with sprayed polymeric materials

Derived from the traditionally used method for spraying cement mortar, various techniques are in use for applying polymeric materials.

NOTE 1 The main difference between this technique family and the spraying of cement mortar is that the two components of the polymer lining are mixed with a specific ratio inside the spray nozzle before spraying and a chemical reaction takes place.

NOTE 2 Techniques of applying a polymeric resin lining by brushing rather than spraying are also state-of-the-art, but are outside the scope of this document.

Table 9 — Features of lining with sprayed polymeric materials

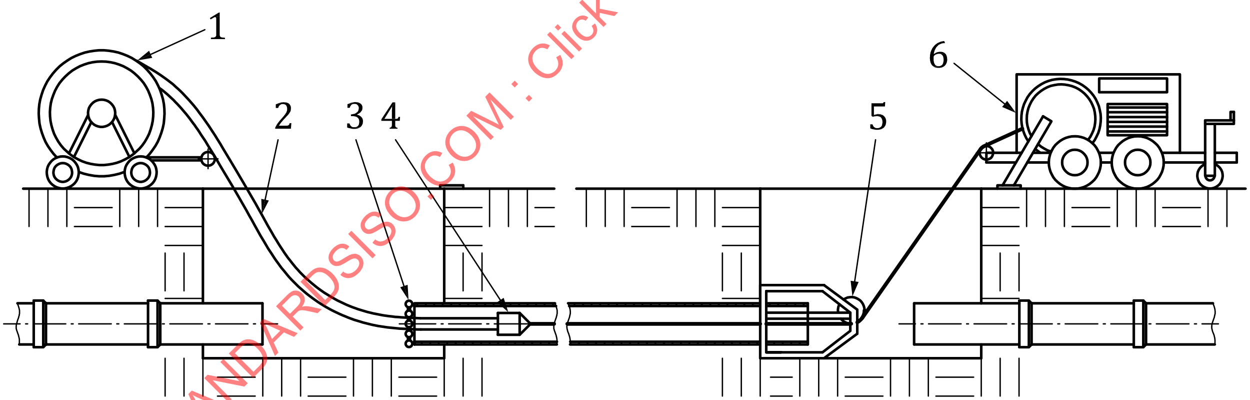
Feature	Description
Relevant documents:	Not yet available
Materials:	Polymeric two-part resin systems (PUR, EP)
Applications:	— pressure pipes; in the case of drinking water, spray lining specific national or local regulations can apply.
Geometric capabilities:	— minimum size: 75 mm; — maximum size: 600 mm; — maximum length: 150 m.
Performance:	— minimal reduction in capacity; — Class B semi-structural renovation; — polymeric layer material determines abrasion resistance.

Table 9 *(continued)*

Feature	Description
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 required; same day return to service.
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.

7.2.11 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 18 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 18 — Schematic representation of lining with inserted hoses

Table 10 — Features of lining with inserted hoses

Feature	Description
Relevant documents:	Not yet available

Table 10 *(continued)*

Feature	Description
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.
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.

7.3 Classification of trenchless replacement techniques

7.3.1 General

Replacement pipeline system functions generally include one or more of the following:

a) utilizing the existing sub-surface space occupied by the existing pipeline structure;

b) upsizing of the existing pipeline structure;

c) installation with minimal disruption of existing customer service;

d) re-alignment of existing pipeline where required.

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

This subclause 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 7.3.2 to 7.3.6 where the different replacement technique families are specified and their respective features, including materials, applications, as well as geometric, performance and installation characteristics, are described.

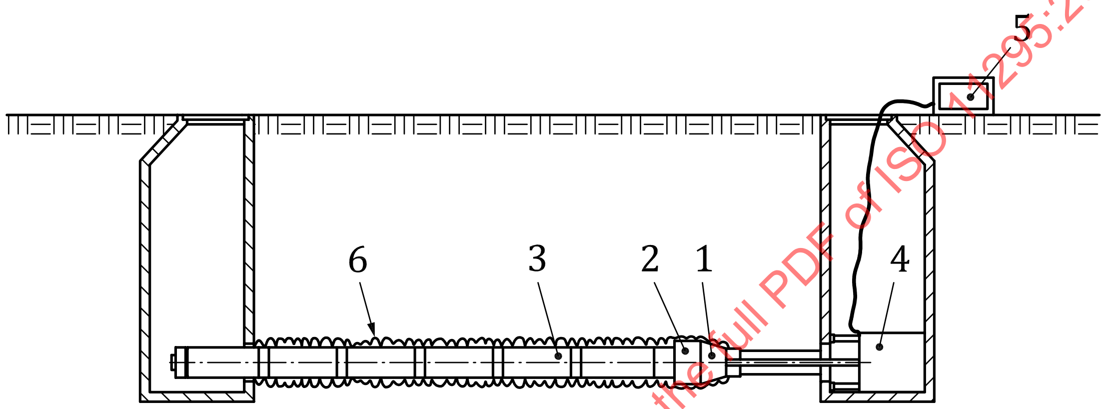
NOTE 1 The pipe materials listed in 7.3.2 to 7.3.6.3 reflect the state-of-the-art improvements in the technique families on the date of publication of this document. Not all technique families/material-combinations are covered by a product standard. The Bibliography gives relevant available documents.

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

7.3.2 Pipe bursting

Replacement is carried out 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 19 (Method A), Figure 20 (Method B) and Table 11]. Methods used are static pipe bursting (Method A) or dynamic pipe bursting (Method B).

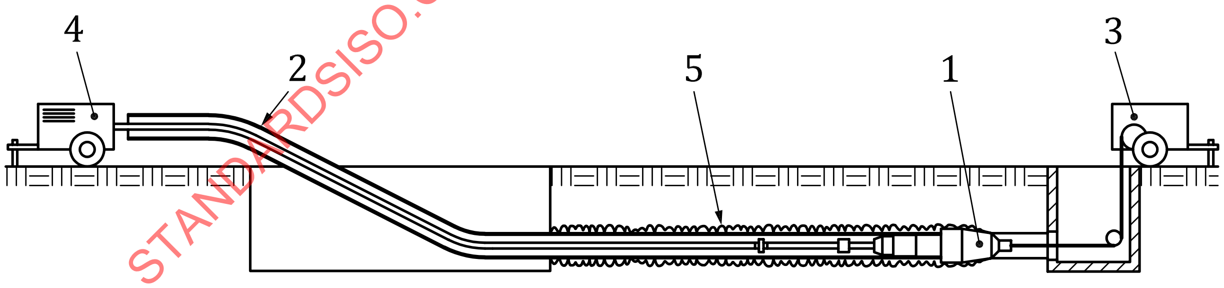
NOTE Dynamic pipe bursting creates impact in the surrounding ground with the potential to damage adjacent infrastructure. For some cases, for example large diameter concrete pipes, the bursting forces can be very high.



Key

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

Figure 19 — 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 20 — 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, ISO 23818-1, 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.
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.

Table 11 *(continued)*

Feature	Description
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.

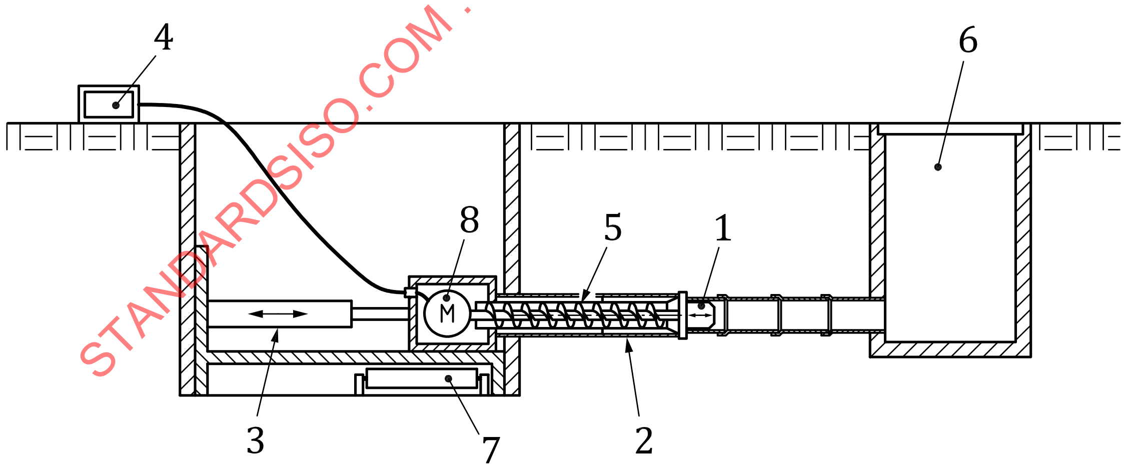
7.3.3 Pipe removal

7.3.3.1 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 21 (Method A), Figure 22 (Method B) and Table 12]. Methods used are pipe eating (Method A) or pipe extraction (Method B).

7.3.3.2 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.



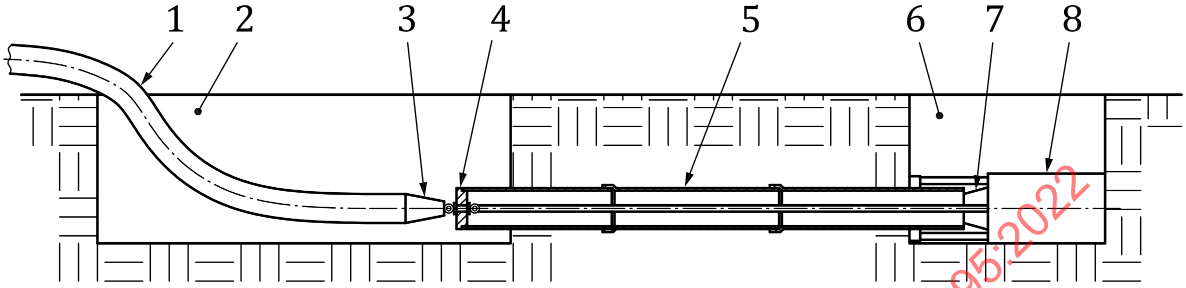
Key

1 microtunnelling machine
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 21 — Schematic representation of replacement by pipe eating method (Method A)

7.3.3.3 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	5	existing pipe; pulling rod inserted
2	entry pit	6	exit pit
3	pulling head	7	pipe splitting / cracking cone
4	pipe extraction adapter	8	hydraulic rod pulling device

Figure 22 — 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, ISO 23818-1, 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: a) microtunnelling machine including auger or slurry system; b) slurry mixing unit; c) generator to power the microtunnelling machine; — with Method B: a) winch (cable or rod pulling); b) rollers with continuous pipe to support the entire length of the pipe string (except where pipe is inserted directly from a coil); c) jointing equipment appropriate to the material.
Surface area:	— for a microtunnelling machineat 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 person-entry access with Method B.

7.3.4 Horizontal directional drilling (HDD)

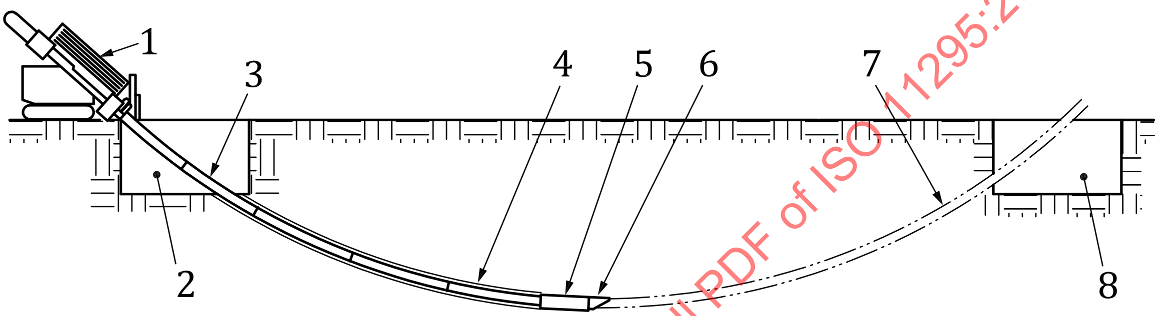
Replacement is carried out off the existing pipeline by using a steerable installation technique (see Figure 23, Figure 24 and Table 13).

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 from collapsing.

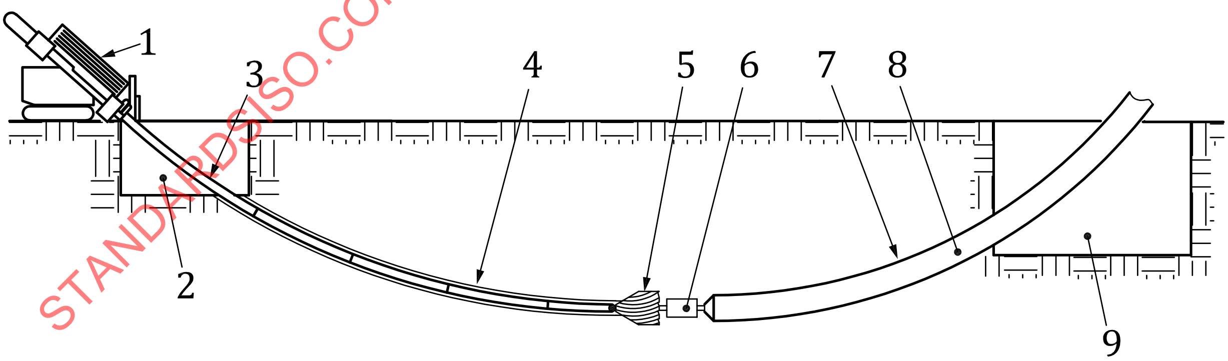
Figure 23 and Figure 24 schematically show the use of the method started from the surface. However, the method can also be used started from pits. This pit-started method is mainly used for steered house connections.



Key

1 drill rig
2 drill entry pit
3 drill string
4 pilot bore
5 transmitter housing
6 drill head
7 planned bore path
8 drill exit pit

Figure 23 — Schematic representation of replacement by horizontal directional drilling — Pilot bore



Key

1 drill rig
2 pipe exit pit with mud sump
3 drill string
4 pilot bore
5 back reamer
6 swivel
7 final bore
8 new pipe
9 pipe entry pit

Figure 24 — Schematic representation of replacement by horizontal directional drilling — Pipe installation

Table 13 — Features of replacement by HDD

Feature	Description
Relevant documents:	ISO 21225-2, ISO 23818-1, EN 12889
Materials:	PE, PP
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 required for the whole insertion length (continuous pipe) or discrete pipes; b) space for drilling fluid mixing tanks and pumps; c) where required, space for control room and slurry treatment system and recycling system; — 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.

Table 13 *(continued)*

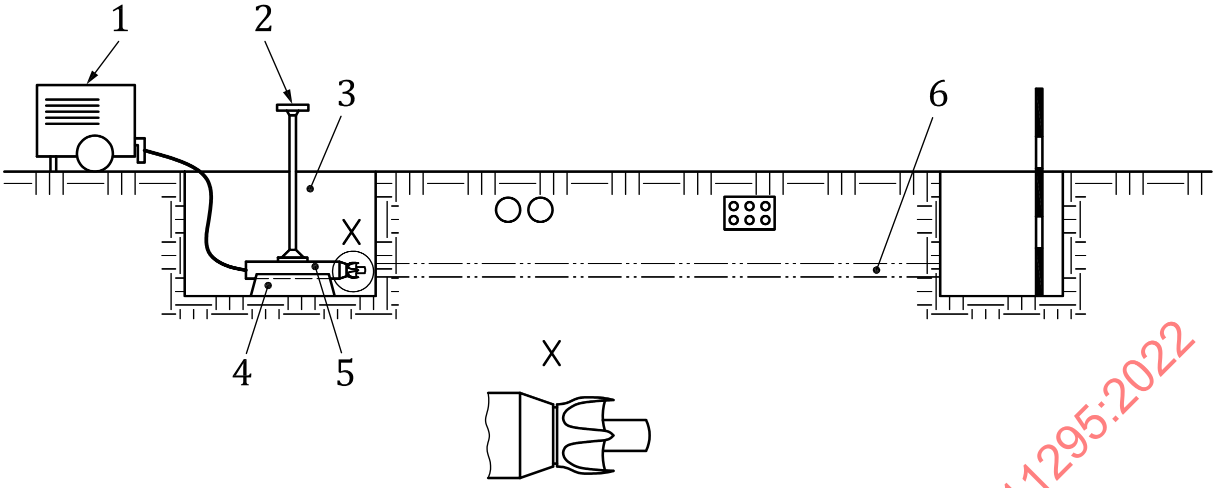
Feature	Description
Surface area:	— for a drilling machine at the receiving end; — for a fluid mixing unit at the receiving end; — for a drilling fluid recycling system where required; — for pipe handling equipment; — for storage of pipes; — for the pipe string (or coil trailer for smaller diameters) 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.

7.3.5 Impact moling

Replacement is carried out off the existing pipeline using a percussive soil displacement hammer or impact mole (see Figure 25 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 launching device
5 impact mole
6 planned bore path

Figure 25 — Schematic representation of replacement by impact moling

Table 14 — Features of replacement by impact moling

Feature	Description
Relevant documents:	ISO 21225-2, ISO 23818-1, EN 12889
Materials:	PE, PP, PVC-U, GRP
Applications:	— non-pressure pipes; — pressure pipes.
Geometric characteristics:	— circular cross-section: — minimum size: 25 mm; — maximum size: 160 mm; — maximum length: 25 m;
Performance:	— hydraulic gradient can be restored within the limits of the procedure; — 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.

Table 14 *(continued)*

Feature	Description
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.

7.3.6 Pipe jacking

7.3.6.1 General

Methods used are auger boring and microtunnelling (see Figure 26, Figure 27 and Table 15). 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.

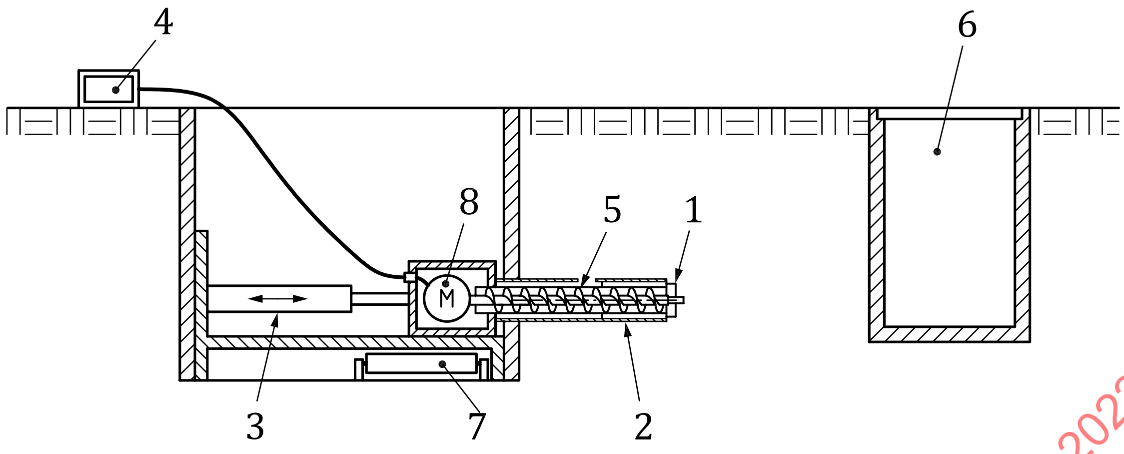
7.3.6.2 Auger boring

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 7.3.3.2) 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

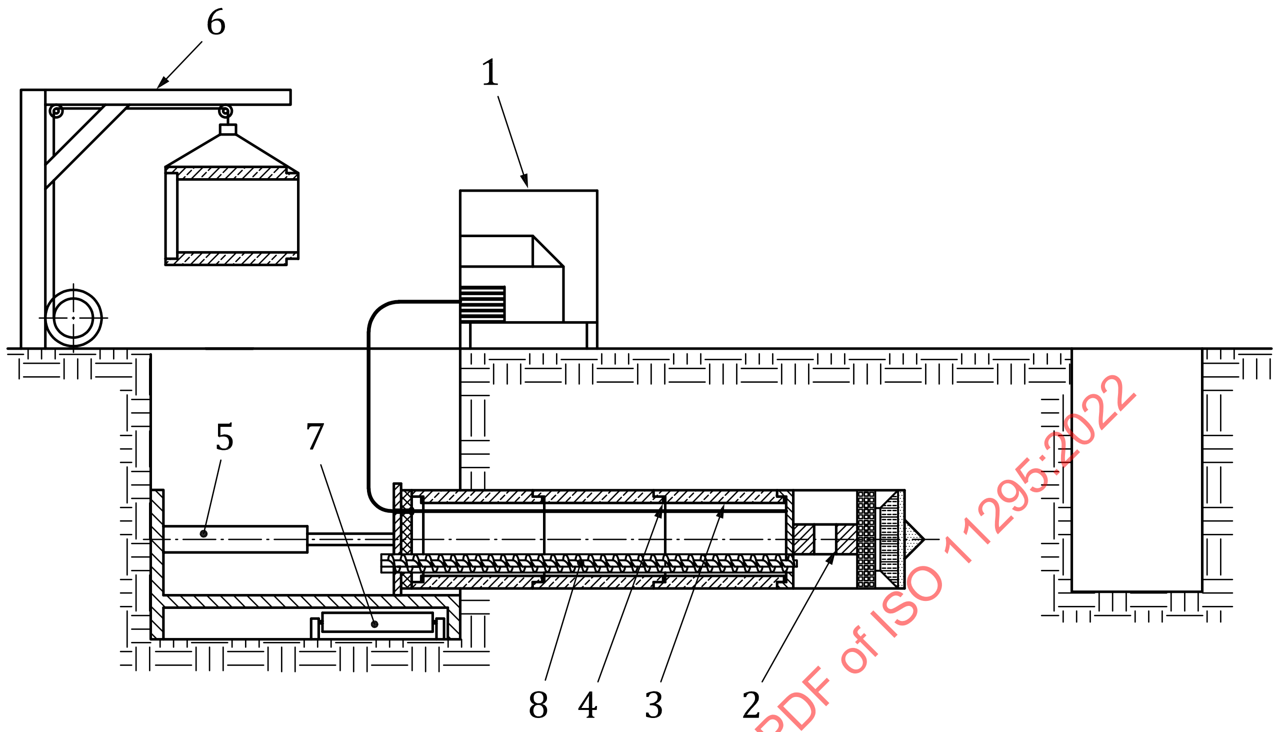
1 cutting head
2 auger casing
3 driving unit in starting pit
4 hydraulic unit
5 auger
6 target pit
7 spoil skip
8 auger drive motor

Figure 26 — Trenchless replacement by pipe jacking — Schematic representation of replacement by (non-steerable) auger boring

7.3.6.3 Microtunnelling

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

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

Figure 27 — 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 within the limits of the procedure; — 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:	— Pipe jacking: Auger and pipe jacking unit, power unit, pipe and auger handling system, spoil handling system. — Microtunnelling: Microtunnelling machine, control room, power unit, slurry handling system, spoil handling system, pipe handling system.
Surface area:	— Pipe jacking: Storage for pipe and auger sections, power unit, spoil handling system, access for spoil, pipe and auger vehicles. — 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 Selection of rehabilitation techniques

8.1 General

After the condition assessment and pre-selection of pipeline rehabilitation options (see 6.5), a detailed analysis and selection of the most appropriate rehabilitation solution shall be performed, where, besides the typical features of the available technique families (see 7.2, 7.3), the economic considerations (costs and benefits) shall be taken into account.

From a technical point of view, the condition assessment data shall be used as a basis.

In addition, the following design criteria shall be taken into account:

— pipeline system layout;

— hydraulic performance;

— structural performance;

— environmental impact;

— construction constraints.

8.2 Pipeline system layout

The location of the existing pipeline is most relevant to the choice of rehabilitation technique.

Individual site requirements, such as crossing of roads, railways and rivers, location of buildings, difficult terrain and risk of damage to and from tree roots, can limit the choice of rehabilitation technique and shall be considered.

A survey of site conditions relevant to pipeline rehabilitation system selection should generally determine and record the following:

a) access to existing pipe, including:

- depth of cover;
- surface type above pipeline;
- manhole or excavation;
- available working area at access points;
- traffic, both vehicular and pedestrian;
- proximity of other services;

b) construction constraints, including:

- ground water table;
- section and/or working lengths;
- gradients;
- changes in direction;
- junctions;
- laterals/services;
- provision for continuity of pipeline service;
- availability of water supply where required by the lining process.

Much of this information can be obtained initially from records and plans, but should always be confirmed by site inspection.

8.3 Hydraulic performance

Determining the hydraulic capacity that is required for the pipeline system is a key factor in the selection of the most economic rehabilitation technique for individual pipelines within it. Possible new performance requirements, e.g. expected changes in flow demand, shall be taken into account. The required capacity fixes the minimum internal dimensions of the installed pipeline system.

Requirements for the fluid carrying capacity of the rehabilitated pipeline system, of which the pipeline forms a part, shall be agreed with the client, including the design working life of the rehabilitated pipeline system.

In the case of water mains, these shall be provided again with valves for air release, both for filling and emptying the pipeline and also for air release under pressure whilst in operation.

The design assumptions made in the fluid capacity calculations shall be documented, e.g. in the installation manual.

NOTE 1 The presence of the liner and the associated reduction in internal diameter of the existing pipe impacts the hydraulic capacity, compared to the condition-based hydraulic capacity of the existing pipe. The hydraulic characteristics of a lined pipe, in particular a close-fit lined pipe, can offset the effect of diameter reduction or even improve capacity.

NOTE 2 For pressure applications, detailed guidance on hydraulic design is provided by EN 805.

8.4 Structural performance

8.4.1 General

Plastics pipes used for renovation can be required to withstand internal and/or external loads in service, where applicable and shall be designed accordingly.

Plastic pipes used for trenchless replacement shall be required to withstand internal and external loads in service and shall be designed accordingly.

The short-term and long-term effects of installation loads shall also be taken into account. The design shall include specifying limits for these installation loads.

In addition, the effects of loads, both internal and external, acting on those parts of the new pipe which are not wholly contained within the existing pipeline structure (e.g. at broken or missing parts of the existing pipeline, in manholes, at fittings, joints, lateral connections and at entry and exit installation excavations), shall be considered, where applicable.

When considering the external loading due to groundwater pressure, the possibilities of short-term saturation of the ground under storm conditions, or even of flood water standing above ground level, should be taken into account.

When aggressive or contaminated soils surround the existing pipelines are involved, any corrosion protection systems shall be restored.

8.4.2 Non-pressure pipes

8.4.2.1 Renovation

Plastics pipes used for renovation of non-pressure pipelines generally require independent ring stiffness to fulfil their structural function.

NOTE 1 Minimum short-term ring stiffness is specified as a function of pipe material in the technique-related parts of the ISO 11296 series. The minimum short-term ring stiffness for each technique family is intended to reflect a minimum long-term load capability to resist a sustained water head of 1 m above pipe invert.

Lining system response to internal pressure as well as external loads can be either positively or negatively influenced by the presence of the existing pipeline, which cannot therefore be ignored, even if severely deteriorated.

NOTE 2 Loads acting on a liner and the associated response of the plastics lining system are not generally comparable with those of a flexible pipe buried directly in soil by open excavation. This is because the lining pipe is installed without disturbing the existing pipe-soil structure, which at least initially continues to be self-supporting and further limits the potential for transfer of soil load to the liner over time.

Loads that should generally be considered include the following, as applicable:

a) installation loads, including:

   1) pipe preparation forces (e.g. section reduction and spiral winding);

   2) insertion forces (tensile, compressive, bending and torsion);

   3) reversion forces (pressure and thermal);

   4) grouting forces (external pressure and flotation);

   5) residual effects of the above installation forces in the permanent works;

b) internal loads, including:

   1) surcharge pressure;

   2) negative pressures: due to hydraulic gradient variations;
   3) thermal loads due to temperature of transported fluid;

c) external loads, including:
   1) ground water pressure;
   2) transferred soil loads, from overburden soil weight and traffic surcharge;
   3) ground movements, from differential settlement, adjacent excavation, soil wetting and drying, soil freeze/thaw cycles and earthquakes;
   4) point loads, from irregularities of the existing pipeline and bedding/backfill conditions;
   5) point loads from lateral connections;
   6) thermal loads due to the environment.

In the case of non-pressure drainage and sewerage networks, components and materials as installed at an ambient temperature of 10 °C, shall be suitable for a continuous water discharge temperature of 45 °C in the case of DNs less than or equal to 200, or of 35 °C for DNs over 200. Components and materials as installed shall also be resistant to corrosion by domestic waste water, surface water and the effects of soil and ground water.

NOTE 3 The resistance to buckling under groundwater pressure and/or negative pressure (vacuum) of a close-fitting liner (or where any annular space is grouted) is substantially enhanced by radial support from the existing pipeline compared with the resistance of a loose-fitting liner.

NOTE 4 Local bending stresses in a liner whether close-fitting or loose-fitting can be substantially increased by the presence of broken pieces of a rigid host pipe. It can therefore be unsafe in liner design to simply neglect the presence of the host pipe on grounds that it is badly deteriorated or can become so.

NOTE 5 Detailed structural design methods are provided by DWA-A 143-2[56], ASTEE 3R[52] and WRc Sewerage Rehabilitation Manual[61].

NOTE 6 Information on the full range of dynamic and permanent ground displacements requiring consideration in design of liners for anti-seismic protection is outside the scope of this document.

8.4.2.2 Replacement

Plastics pipes installed by replacement techniques will generally have a fluid annulus after installation and therefore can be susceptible to unrestrained hydrostatic buckling in the short to medium term before natural consolidation of the surrounding soil fills the annular space. After taking this into account, design for the long term should be carried out as described in 8.4.2.1.

NOTE For replacement techniques, resistance to installation forces is generally the critical consideration in pipe design.

8.4.3 Pressure pipes

8.4.3.1 Renovation

Plastics pipes used for renovation of pressure pipelines generally require internal pressure resistance and ring stiffness to fulfil their structural function. The structural action of pressure pipe liners is classified as indicated in Table 16.