INTERNATIONAL STANDARD

ISO 11296-4

Second edition
2018-02

Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks —

Part 4:
Lining with cured-in-place pipes

Systèmes de canalisations en plastique pour la rénovation des réseaux de branchements et de collecteurs d'assainissement enterrés sans pression —

Partie 4: Tubage continu par tubes polymérisés sur place

Reference number
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Foreword

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

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

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

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

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

This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 8, *Rehabilitation of pipeline systems*

This second edition cancels and replaces the first edition (ISO 11296-4:2009), which has been technically revised.

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

— the service temperature range has been explicitly stated in the scope;

— in Clause 3, new definitions have been added for temporary, permanent and semi-permanent membranes, with Annex A and the definition of preliner updated accordingly; for nominal wall thickness specialized for CIPP; and for service temperature and type testing adopted from other standards;

— type "R" and "E-CR" glass fibres have been added to Table 1;

— the requirements on "M" stage strength characteristics of the neat resin system have been removed in Table 2, as they have been effectively covered in Table 5 by the "I" stage requirements on mechanical characteristics of the cured composite;

— new requirements for the nature of the bond of any semi-permanent internal membrane to the underlying composite, and for declaration of class of composite in accordance with ISO 14125, have been added in 8.1;

— a new subclause has been added to 8.5 to specify reference temperature for testing, and procedure for determining temperature re-rating factors where required;

— separate tables for short and long-term mechanical characteristics have been created in 8.5, and minima for declared values removed except for ring stiffness, strain capacity and creep factor;

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— the following have been added to Table 6:

a) option of ring test for wet creep factor;

b) test for long-term flexural strength under dry or wet conditions by the method detailed in the new Annex D;

— a test for stress corrosion (new Annex D test in acid environment) has been added to Table 7;

— further requirements for documenting specific installation parameters and procedures, and the related environmental precautions, in the installation manual for each individual CIPP technique, have been added in 9.4;

— requirements for documentation in the installation manual of technique-specific methods for sealing liner connections at manholes and laterals have been added in 9.7;

— Annex B has been revised to relax curvature restriction on 3-point bend test samples, and to include a full new procedure for calculation and reporting of test results without partial reference to ISO 178;

— the previous Annexes C and D has been merged into a single new Annex C specifying a common procedure for determination of long-term modulus under either dry or wet conditions.

A list of all the parts in the ISO 11296 series can be found on the ISO website.

Introduction

System standards dealing with the following applications are either available or in preparation:

— ISO 11296, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks* (this document);

— ISO 11297, *Plastics piping systems for renovation of underground drainage and sewerage networks under pressure*;

— ISO 11298, *Plastics piping systems for renovation of underground water supply networks*;

— ISO 11299, *Plastics piping systems for renovation of underground gas supply networks*.

These system standards are distinguished from those for conventionally installed plastics piping systems because they set requirements for certain characteristics in the "as-installed" condition after site processing. This is in addition to specifying requirements for plastics piping system components, "as manufactured".

This document (system standard) comprises a

— *Part 1: General*

and the following technique family-related parts:

— *Part 2: Lining with continuous pipes*;

— *Part 3: Lining with close-fit pipes*;

— *Part 4: Lining with cured-in-place pipes*;

— *Part 5: Lining with discrete pipes*;

— *Part 7: Lining with spirally-wound pipes*;

— *Part 8: Lining with pipe segments*;

— *Part 9: Lining with a rigidly anchored plastics inner layer*;

— *Part 10: Lining with sprayed polymeric materials*.

The requirements for any given renovation technique family are given in ISO 11296-1 applied in conjunction with the other relevant parts. For example, both ISO 11296-1 and this document together specify the requirements relating to lining with cured-in-place pipes. For complementary information, see ISO 11295. Not all technique families are applicable to every area of application and this is reflected in the part numbers included in each system standard.

A consistent structure of clause headings has been adopted for all parts to facilitate direct comparisons across renovation technique families.

Figure 1 shows the common structure and the relationship between ISO 11296 and the system standards for other application areas.

Plastics piping systems

Renovation

Applications

Gas supply networks

Water supply networks

Drainage and sewerage networks under pressure

Non-pressure drainage and sewerage networks

System Standards

ISO 11299

ISO 11298

ISO 11297

ISO 11296

Part 1: General
Part 2: Lining with continuous pipes
Part 3: Lining with close-fit pipes
Part 4: Lining with cured-in-place pipes
Part 5: Lining with discrete pipes
Part 7: Lining with spirally-wound pipes
Part 8: Lining with pipe segments
Part 9: Lining with rigidly anchored plastics inner layer
Part 10: Lining with sprayed polymeric materials

Clause 1: Scope
Clause 2: Normative references
Clause 3: Terms and definitions
Clause 4: Symbols and abbreviated terms
Clause 5: Pipes at the "M" stage
Clause 6: Fittings at the "M" stage
Clause 7: Ancillary components
Clause 8: Fitness for purpose of the installed lining system at the "I" stage
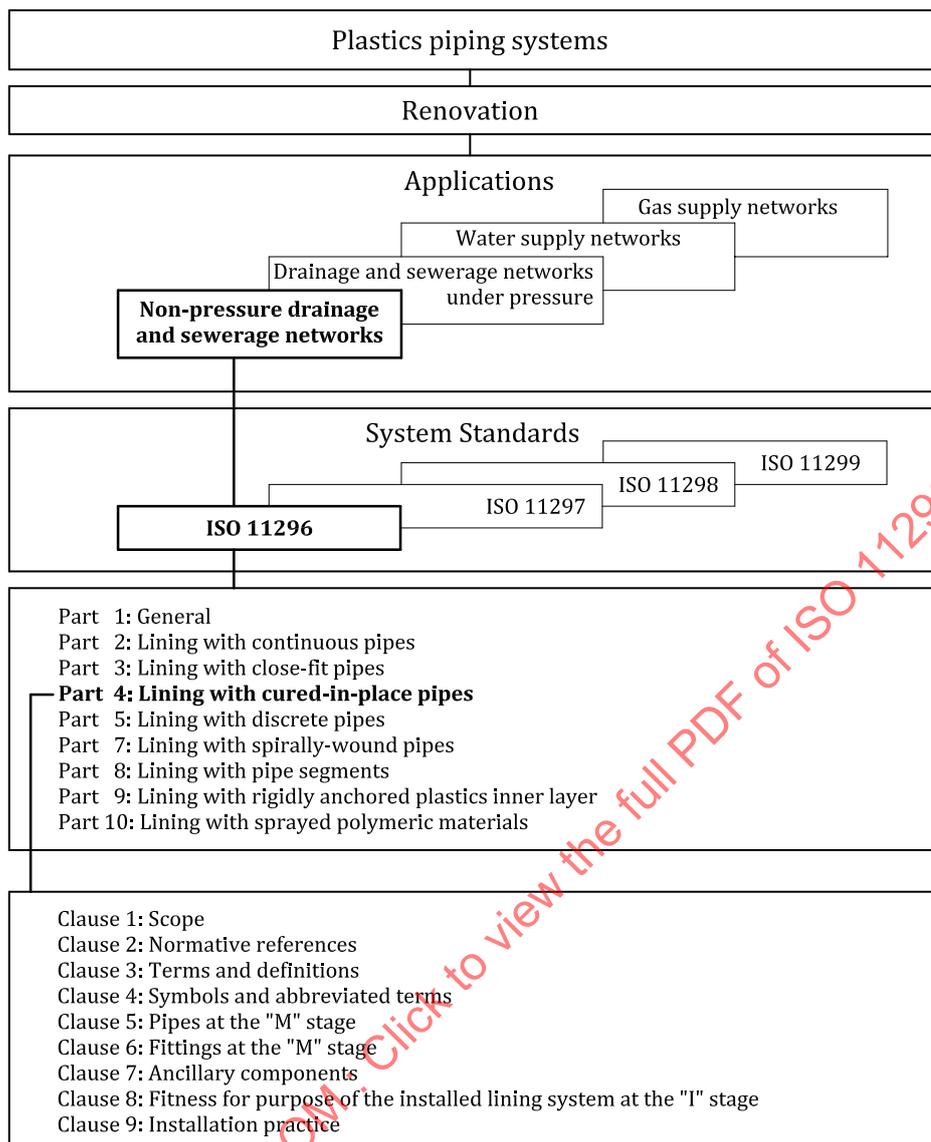Clause 9: Installation practice

Figure 1 — Format of the renovation system standards

Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks —

Part 4:
Lining with cured-in-place pipes

1 Scope

This document, in conjunction with ISO 11296-1, specifies requirements and test methods for cured-in-place pipes and fittings used for the renovation of underground non-pressure drainage and sewerage networks with service temperatures up to 50 °C.

It applies to the use of various thermosetting resin systems, in combination with compatible fibrous carrier materials, reinforcement, and other process-related plastics components (see 5.3).

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 75-2:2013, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite*

ISO 178:2010+A1:2013, *Plastics — Determination of flexural properties*

ISO 899-2:2003, *Plastics — Determination of creep behaviour — Part 2: Flexural creep by three-point loading*

ISO 3126, *Plastics piping systems — Plastics components — Determination of dimensions*

ISO 4435, *Plastics piping systems for non-pressure underground drainage and sewerage — Unplasticized poly(vinyl chloride) (PVC-U)*

ISO 7684, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the creep factor under dry conditions*

ISO 7685:1998, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of initial specific ring stiffness*

ISO 8513:2016, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test methods for the determination of the initial longitudinal tensile strength*

ISO 8773, *Plastics piping systems for non-pressure underground drainage and sewerage — Polypropylene (PP)*

ISO 10467:—[1]), *Plastics piping systems for drainage and sewerage with or without pressure — Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) — Specifications for pipes, fittings and joints*

ISO 10468, *Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the long-term specific ring creep stiffness under wet conditions and calculation of the wet creep factor*

ISO 10928:2016, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Methods for regression analysis and their use*

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1)   To be published. (Revises ISO 10467:2004)

ISO 10952, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Determination of the resistance to chemical attack for the inside of a section in a deflected condition*

ISO 11296-1:2018, *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 1: General*

ISO 13002, *Carbon fibre — Designation system for filament yarns*

ISO 14125:1998+A1:2011, *Fibre-reinforced plastic composites — Determination of flexural properties*

EN 14364:2013, *Plastics piping systems for drainage and sewerage with or without pressure. Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP). Specifications for pipes, fittings and joints*

3   Terms and definitions

For the purposes of this document the terms and definitions given in ISO 11296-1 and the following apply.

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

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

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

3.1   General terms

3.1.1
abrasion layer
inner layer of composite of declared thickness provided as a sacrificial layer for anticipated abrasion of the *CIPP product* (3.1.3) in service

3.1.2
carrier material
porous component of the liner, which carries the liquid *resin system* (3.1.16) during insertion into the pipe being renovated and forms part of the installed lining system once the resin has been cured

3.1.3
CIPP product
cured-in-place pipe product
cured-in-place pipe of a particular design, produced from a liner of specified materials, with a wall structure which is uniquely defined for each diameter/wall thickness combination, and which is impregnated with a specific *resin system* (3.1.16) and installed by a specific process

3.1.4
CIPP unit
specific cured-in-place pipe produced from a continuous liner, which has been impregnated in one process and installed as a single length

3.1.5
close fit
situation of the outside of the installed liner relative to the inside of the existing pipeline, which can either be an interference fit or include a small annular gap resulting from shrinkage and tolerances only

3.1.6
composite
combination of cured *resin system* (3.1.16), *carrier material* (3.1.2) and/or *reinforcement* (3.1.15), excluding any internal or external membranes

3.1.7
curing
process of resin polymerization, which may be initiated or accelerated by the use of heat or exposure to light

3.1.8
design thickness
required wall thickness of the *composite* (3.1.6), excluding any *abrasion layer* (3.1.1), as determined by structural design

3.1.9
first break
elastic limit or first major discontinuity of the stress-strain curve associated with local failure of the resin matrix or reinforcing fibres

3.1.10
lateral connection collar
fitting for reconnecting a lined main pipe to an existing or renovated lateral pipe

3.1.11
lining tube
flexible tube, consisting of *carrier material* (3.1.2) , *resin system* (3.1.16) and any membranes and/or *reinforcement* (3.1.15), as combined prior to insertion in the pipe to be lined

3.1.12
nominal CIPP wall thickness
one of a range of discrete lining tube wall thicknesses dictated by the sum of the thicknesses of the individual layers of materials used for tube construction at the "M" stage

3.1.13
permanent membrane
internal or external membrane designed to retain its integrity through the processes of lining tube insertion and *resin system* (3.1.16) cure, and to provide functions for the operational life of the CIPP liner

3.1.14
preliner
permanent or semi-permanent external membrane which is installed separately before the insertion of the resin-impregnated *lining tube* (3.1.11)

3.1.15
reinforcement
fibres incorporated in the liner which enhance the dimensional stability of the liner and/or the structural properties of the cured *composite* (3.1.6)

Note 1 to entry: The reinforcement can be incorporated in the *carrier material* (3.1.2), constitute the carrier material, or can be a separate layer.

3.1.16
resin system
thermosetting resin including the *curing* (3.1.7) agent(s) and any fillers or other additives in specified proportions

3.1.17
semi-permanent membrane
internal or external membrane designed to retain its integrity through the processes of *lining tube* (3.1.11) insertion and *resin system* (3.1.16) cure, but not relied on to retain its integrity at the "I" stage

3.1.18
service temperature
maximum sustained temperature at which a system is expected to operate

Note 1 to entry: Service temperature is expressed in degrees Celsius (°C).

3.1.19
temporary membrane
membrane forming the internal or external surface of the pipe at the "M" stage, with functions at the "M" stage only

Note 1 to entry: It is removed during or after the installation.

3.1.20
total thickness
thickness of CIPP at the "I" stage comprising the *composite* (3.1.6) and any *semi-permanent* (3.1.17) and *permanent membranes* (3.1.13)

3.1.21
type testing
testing performed to prove that the material, product, joint or assembly is capable of conforming to the requirements given in the relevant standard

3.2 Techniques

3.2.1
inversion
process of turning a flexible tube or hose inside out by the use of fluid (water or air) pressure

3.2.2
inverted-in-place insertion
method whereby the impregnated lining tube is introduced by *inversion* (3.2.1) to achieve simultaneous insertion and inflation

3.2.3
winched-in-place insertion
method whereby the flat impregnated lining tube is first pulled into the pipe to be lined and then inflated to bring it up to size

Note 1 to entry: With some techniques, inflation is achieved by *inversion* (3.2.1) through the pulled-in *lining tube* (3.1.11) of a separate impregnated tube or dry hose, which is either withdrawn after resin cure or left in place as a permanent internal membrane.

4 Symbols and abbreviated terms

4.1 Symbols

b width of test piece

C_E correction factor on 3-point flexural modulus for curvature of test piece

C_σ correction factor on 3-point flexural stress for curvature of test piece

d_m mean diameter of pipe sample at mid-thickness of the composite (= $2R_2$)

d_n nominal outside diameter

E_0 short-term flexural modulus

E_c	apparent flexural modulus of curved 3-point bend test piece before correction for curvature
E_f	apparent flexural modulus of flat 3-point bend test piece
E_x	long-term flexural modulus at x years
E_t	flexural creep modulus at time, t
e_1	thickness of the internal membrane
e_2	thickness of the external membrane
e_c	thickness of the composite
e_{tot}	total thickness
$e_{c,m}$	mean thickness of the composite
$e_{c,min}$	minimum thickness of the composite
F	force applied in flexural test
h	total thickness of the test piece
h_m	mean total thickness of the test piece
I	moment of inertia (the second moment of area) per unit length of the pipe wall
L	distance between supports in flexural test
L_1	distance between points of contact of curved flexural test piece with supports
L_2	true span of the curved flexural test piece
L_3	total chord length of the curved flexural test piece
r	radius of the support
R_2	radius of curvature of the test piece at mid-thickness of the composite
R_1	radius of curvature of the inside surface of test piece
V	rise of centre of the curved flexural test piece above its points of contact with supports
s	deflection measured in flexural test
s_t	deflection of flexural test piece at time, t
S_0	initial specific ring stiffness
t	elapsed time in long-term test
x	time to which long-term test results are extrapolated for design purposes
α_x	creep factor at x years
ε_c	apparent flexural strain in curved 3-point bend test piece before correction for curvature
ε_{f0}	initial flexural strain at zero stress
ε_{fb}	flexural strain at first break

ε_{fM} flexural strain at maximum applied load

σ_0 required flexural stress in creep test

σ_c apparent flexural stress in curved 3-point bend test piece before correction for curvature

σ_f flexural stress in flat 3-point bend test piece

σ_{fb} flexural stress at first break

σ_{fM} flexural stress at maximum applied load

σ_L ultimate longitudinal tensile stress

σ_x long-term flexural strength at x years

ϕ half-angle of arc of a 3-point bend test piece between its points of contact with the supports

4.2   Abbreviated terms

CIPP   Cured-in-place pipe

EP   Epoxy resin

GRP   Glass-reinforced thermosetting plastics

PA   Polyamide

PAN   Polyacrylonitrile

PE   Polyethylene

PEN   Poly(ethylene naphthate)

PET   Poly(ethylene terephthalate)

PVC-U Unplasticized poly(vinyl chloride)

PPTA   Aramid

UP   Unsaturated polyester resin

VE   Vinyl ester resin

5   Pipes at the "M" stage

NOTE   This clause specifies requirements for the lining tube (i.e. all components before resin cure). Requirements for the cured composite are specified in Clause 8.

5.1   Materials

Lining tubes shall comprise at least the following components:

— resin system;

— carrier material.

In addition, they may optionally comprise

— a reinforcement,

— an internal membrane (permanent, semi-permanent or temporary), and

— an external membrane (permanent, semi-permanent or temporary).

For the relationship between these components, see Figure 2.

NOTE 1   Various components can have an end product or purely process-related functions dependent on the specific method used. The possible functions of components are given in Table A.1.

NOTE 2   The carrier material can itself have a reinforcing effect.
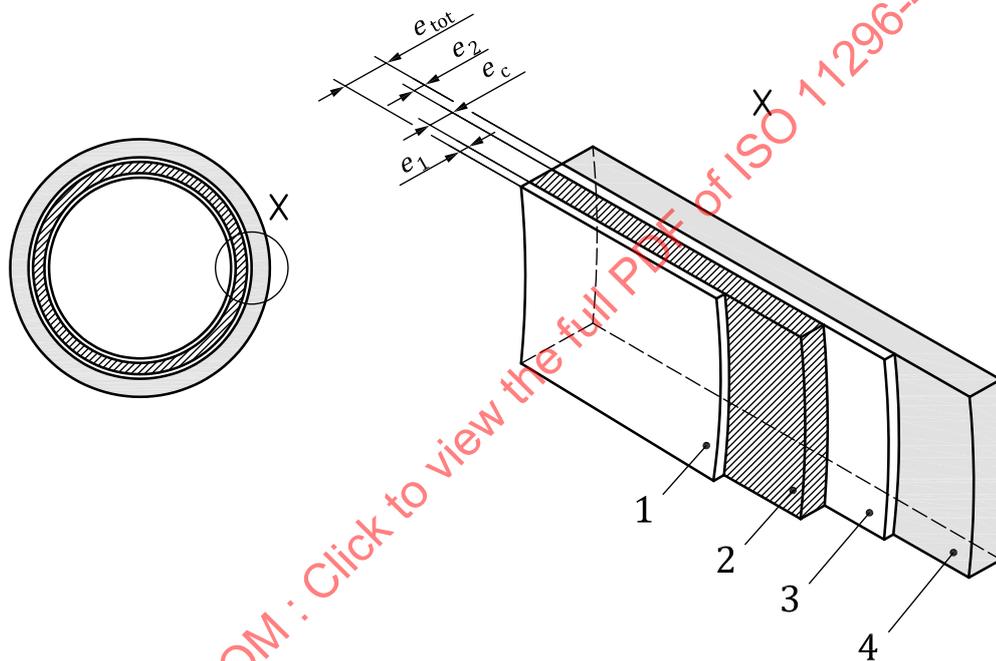
Key
1   internal membrane
2   composite (resin in carrier material/reinforcement, including any abrasion layer)
3   external membrane
4   existing pipeline

Figure 2 — Typical wall construction of lining tube

Lining tube components shall comprise materials conforming to Table 1 and the material used for each component shall be declared.

Table 1 — Materials for lining tube components

Lining tube component	Materials
Resin system: — resin type	UP, VE or EP[a]
— filler type	None, inorganic or organic
— curing agent type	Heat-initiated, light-initiated or ambient cure
Carrier material/reinforcement	Polymeric fibres: PA, PAN, PEN, PET, PP or PPTA
	Glass fibres of types "E", "C" , "R" and/or "E-CR" conforming to ISO 10467:—
	Carbon fibres of declared designation conforming to ISO 13002
	Combinations of the above fibres[b]
Membranes	Unrestricted[c]

[a]   Other resin systems are current state of the art and, although excluded from the scope, can in principle be tested in accordance with this document.

[b]   Where a combination of fibres is used, the proportions by mass of each fibre type shall be declared to within 5 %.

[c]   As there are no requirements for membranes, there are also no restrictions on the choice of thermoplastic materials used for membranes.

5.2   General characteristics

Colouration may be used for resin mix and/or impregnation control.

5.3   Material characteristics

When tested in accordance with the methods given in Table 2, the resin system, cast singly without filler, carrier material or reinforcement, shall, after cure, conform to the material requirements specified in Table 2, according to resin type.

Table 2 — Material characteristics of resin systems

Characteristic	Requirement	Test parameter		Test method
		Parameter	Value	
Temperature of deflection under load	For UP and VE ≥85 °C For EP: ≥70 °C	Orientation of test piece Number of test pieces	Edgewise 3	ISO 75-2:2013, Method A

5.4   Geometric characteristics

No geometric requirements apply at the "M" stage.

The perimeter of the lining tube should be dimensioned such that when installed, it forms a close fit to the existing sewer wall or as otherwise required by the design. The manufactured length and thickness of the lining tube should include allowances for any longitudinal and circumferential stretch during installation.

5.5   Mechanical characteristics

There can be technique and/or project-specific strength and stiffness requirements for the installation of the lining tube (see 9.4.2).

5.6   Physical characteristics

No physical requirements apply.

5.7 Jointing

The lining tube after impregnation shall be provided in lengths such that no jointing is required between points of access to the sewer.

5.8 Marking

The marking shall conform to ISO 11296-1:2018, 5.8. It shall be applied to the outside of the lining tube as delivered to the installation site or in the case of pre-packaged lining tubes, on the outside of the packaging.

For compliance with ISO 11296-1:2018, 5.8 c), the dimension marked shall be the nominal outside diameter or, in the case of lining tubes to be installed in non-circular sewers, the diameter of the circle having the same outside perimeter as the lining tube.

For compliance with ISO 11296-1:2018, 5.8 d), the dimension marked shall be the nominal CIPP wall thickness.

For compliance with ISO 11296-1:2018, 5.8 f), the manufacturer's information shall enable the identification of the lining tube structure and (if pre-impregnated) the resin system used.

6 Fittings at the "M" stage

NOTE   This clause describes the various materials which a cured-in-place fitting conforming to this document can comprise, and specifies requirements relating to those materials and intermediate fabrications at the "M" stage. For "I" stage requirements, see Clause 8.

6.1 Materials

The only cured-in-place fittings covered by this document are lateral connection collars. Such collars can be an integral part of a complete lining of a lateral pipe. External saddle connections between cured-in-place main pipes and lateral pipes can also be made with standard thermoplastic or GRP fittings.

Lateral connection collars shall comprise cured-in-place components conforming to 5.1, but may also include additional thermoplastic components of declared composition.

External saddles shall be of PP, PVC-U or GRP-UP, conforming to ISO 4435, ISO 8773 or EN 14364:2013, 6.5, as applicable.

6.2 General characteristics

No general requirements apply.

6.3 Material characteristics

The resin system of cured-in-place fittings shall conform to 5.3.

6.4 Geometric characteristics

Cured-in-place lateral connection collars shall be classified, as indicated in Table 3, according to the minimum distance extended into the lateral pipe.

Table 3 — Classification of cured-in-place lateral connection collars

Class[a]	Minimum extension into lateral pipe
A	1 000 mm
B	400 mm and at least 150 mm beyond first joint in existing lateral pipe
C	100 mm
[a] This classification applies where the diameter of the lateral pipe is less than or equal to DN 200.	

In addition, the rim of any cured-in-place lateral connection collar shall overlap the main pipe by not less than 50 mm (see Figure 3).

a) Top-hat   **b) Tee piece**
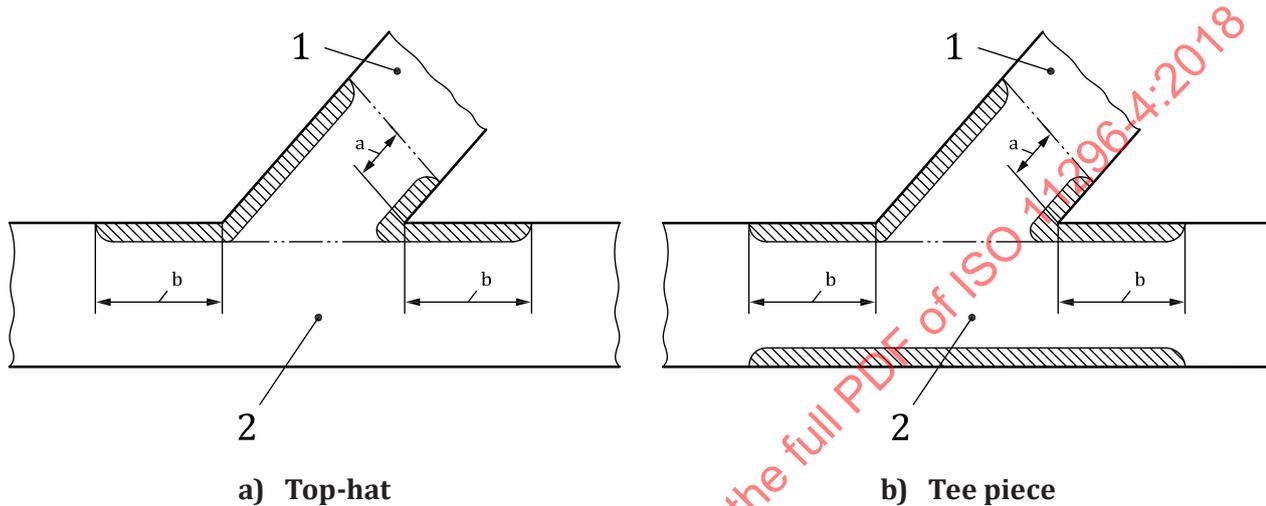
Key
1   lateral pipe
2   main pipe
a   Extension of colllar.
b   Rim of collar.

Figure 3 — Schematic of cured-in-place lateral connection collars

6.5   Mechanical characteristics

No mechanical requirements apply to cured-in-place fittings at the "M" stage.

6.6   Physical characteristics

No physical requirements apply to cured-in-place fittings.

6.7   Jointing

Joints shall be either mechanical or adhesive.

6.8   Marking

The marking shall conform to ISO 11296-1:2018, 6.8. It shall be applied to the outside of the lining tube as delivered to the installation site or, in the case of pre-packaged lining tubes, on the outside of the packaging.

As specified in ISO 11296-1:2018, 6.8 c), the dimension marked shall be the nominal outside diameter of the part of the lateral connection collar which fits into the lateral pipe.

As specified in ISO 11296-1:2018, 6.8 d), the dimension marked shall be the nominal CIPP wall thickness.

As specified in ISO 11296-1:2018, 6.8 f), the manufacturer's information shall enable the identification of the lining tube structure and (if pre-impregnated) the resin system used.

7 Ancillary components

This document does not apply to any ancillary components.

8 Fitness for purpose of the installed lining system at the "I" stage

NOTE   This clause includes the requirements for the finished CIPP system, the manufacture of which, by definition, is not completed until the resin is cured at the "I" stage.

8.1 Materials

The pipe and any fittings may consist of different mutually compatible material components selected from the ranges defined in 5.1 and 6.1. The nature of the bond of any semi-permanent internal membrane to the underlying composite shall be such as to prevent large pieces becoming detached and risking blockage of the sewer as a result of abrasion or jetting in service.

NOTE   This document does not specify requirements for any end product functions of internal membranes (see Annex A).

The material class of the composite in accordance with ISO 14125:1998+A1:2011, Table 3 shall be declared.

8.2 General characteristics

In straight lengths of pipe of constant internal perimeter, the CIPP shall not introduce surface irregularities in addition to those of the existing pipeline, which exceed 2 % of the nominal diameter or 6 mm, whichever is greater.

NOTE 1   This requirement can be changed, where appropriate, to meet hydraulic performance requirements of the lined pipe.

NOTE 2   A feature of cured-in-place pipes is that they generally conform to the surface features of the existing pipeline. At bends and at irregularities in the existing pipeline, including local reductions of internal perimeter, folding generally occurs.

8.3 Material characteristics

Resin cure shall be demonstrated by conformity to 8.5.

8.4 Geometric characteristics

8.4.1 General

NOTE   The likelihood of local folding of CIPP at bends, changes of cross-section or stepped joints in the existing pipe (see 8.2) can affect the minimum free bore attainable in the renovated pipeline.

8.4.2 CIPP wall structure

The thicknesses and relative positions of each component layer of the CIPP wall, including tolerances, shall be specified as declared values. The maximum proportional volume of any entrained air and/or evolved gas shall likewise be specified. The wall structure shall be verified by visual examination of the

edge of a cut section of a pipe, with magnification as necessary, and use of a scale or caliper capable of measuring to within 0,1 mm.

NOTE   For the purposes of verifying that any entrained air and/or evolved gas does not exceed the declared maximum proportional volume, microscopic examination of a thin section can be carried out. For uniform composites only, measurement of test piece density can also provide a useful guide.

8.4.3   Wall thickness

When measured in a laboratory in accordance with the relevant test method specified, the wall thickness of the installed pipe shall conform to the requirements of Table 4.

NOTE   Wall thickness measured along the cut edge of the CIPP at manholes or lateral openings might not be representative of the main body of the liner.

Table 4 — Geometric characteristics

Characteristic	Requirement	Test method
Mean wall thickness, $e_{c,m}$, of the composite	Not less than the design thickness (plus the thickness of any abrasion layer)	B.4.1
Minimum wall thickness, $e_{c,min}$, of the composite	Not less than 80 % of the design thickness (plus the thickness of any abrasion layer), or 3 mm, whichever is greater[a]	
a The $e_{c,min}$ requirement does not apply to points where local wall thickness reduction is caused by irregularity in the existing pipeline.		

8.5   Mechanical characteristics

8.5.1   Reference conditions for testing

All mechanical characteristics specified in this document shall, unless otherwise specified, be determined at a temperature of (23 ± 2) °C. For long term service temperatures greater than 35 °C and up to and including 50 °C, type tests shall, unless otherwise specified, be carried out within 5 °C of, but at not less than, the design service temperature, to establish re-rating factors for all long-term characteristics to be used in design.

NOTE 1   Re-rating factors can also be determined for service temperatures of 35 °C or less, if required by the client.

NOTE 2   For municipal applications, the operating temperature in DN ≤ 200 including house connections is typically up to 45 °C, but for sizes DN > 200 is up to 35 °C.

Unless otherwise specified, or in case of dispute, test pieces shall be preconditioned by storing in air at the specified test temperature for at least 24 h prior to testing.

8.5.2   Test requirements

When tested in accordance with the methods given in Tables 5 and 6, the mechanical characteristics of pipe samples taken from actual or simulated installations in accordance with 8.8 shall conform to these tables. The extensions into the lateral pipe of Class A and B lateral connection collars as defined in Table 3 shall be considered as pipes.

Where requirements are specified in Tables 5, 6 and 7 as declared values, these declarations shall be documented for each CIPP product, with supporting test data or references to such data, in the installation manual for that product.

Table 5 — Short-term mechanical characteristics of pipes

Characteristic	Requirement[a]	Test parameters		Test method
		Parameter	**Value**	
Initial specific ring stiffness, S_0	Declared value, but not less than 0,25 kPa	Number of test pieces Test piece length for — $d_n \leq 300$ mm — $d_n > 300$ mm For method B: relative deflection	2 $d_n \pm 5$ % (300 ± 15) mm (3 ± 0,5) %	ISO 7685:1998, Method A or Method B[b]
Short-term flexural modulus, E_0	Declared value in MPa	Number of test pieces Speed of testing Sample orientation	5 10 mm/min Shall conform to 8.8	Annex B
Flexural stress at first break, σ_{fb}	Declared value in MPa			
Flexural strain at first break, ε_{fb}	Declared value but not less than 0,75 %			
Ultimate longitudinal tensile stress, σ_L	Declared value in MPa	Number of test pieces Speed of testing	5 5 mm/min	ISO 8513:2016, Method A or Method B[b]
Ultimate elongation	Declared value but not less than 0,5 %			
[a] Declared values refer to the mean value of each characteristic as determined from the results of tests on a set of the specified number of test pieces.				
[b] In case of dispute, method A applies.				

Table 6 — Long-term mechanical characteristics of pipes

Characteristic	Requirement[a]	Test parameters		Test method
		Parameter	**Value**	
Dry creep factor[a] $\alpha_{x, dry}$	Declared value but not less than $(0{,}125 \text{ kPa})/S_0$ [c]	Method 1 (ring test)[b] — number of test pieces — test piece length for $d_n \leq 300$ mm $d_n > 300$ mm — method for measuring S_0 — initial strain — test period — time to which values are to be extrapolated — relative humidity	5 $d_n \pm 5$ % (300 ± 15) mm constant load $(0{,}25 \pm 0{,}2)$% 10 000 h 50 years (i.e. $x = 50$) 50 ± 10) %	ISO 7684 with extrapolation according to ISO 10468
Long-term flexural modulus under dry conditions[a], $E_{x, dry}$	Declared value in MPa	Method 2 (3-point flexural test) — number of test pieces — sample orientation — test period — time to which values are to be extrapolated — relative humidity	5 Shall conform to 8.8 10 000 h 50 years (i.e. $x = 50$) (50 ± 10) %	Annex C
Wet creep factor[a], $\alpha_{x, wet}$	Declared value but not less than $(0{,}125 \text{ kPa})/S_0$ [c]	Method 1 (ring test)[b] — number of test pieces — test piece length for $d_n \leq 300$ mm $d_n > 300$ mm — method for measuring S_0 — initial strain — test period — time to which values are to be extrapolated	5 $d_n \pm 5$ % (300 ± 15) mm constant load $(0{,}25 \pm 0{,}2)$% 10 000 h 50 years	ISO 10468
[a] It is expected that only one of these methods of creep testing (dry or wet) will be applied, according to national preferences.				
[b] Where it is difficult to acquire a full ring for testing, method 2 provides a practical alternative to method 1.				
[c] To provide a long-term ring stiffness, S_{50}, of not less than 0,125 kPa.				
[d] It is expected that only one of these methods of long-term strength testing (dry or wet or in acid; see Table 7) will be applied, according to national preferences.				
[e] Required for design of non-circular liners.				

Table 6 *(continued)*

Characteristic	Requirement[a]	Test parameters		Test method
		Parameter	Value	
Long-term flexural modulus under wet conditions[a], $E_{x, wet}$	Declared value in MPa	Method 2 (3-point flexural test) — number of test pieces — sample orientation — test period — time to which values are to be extrapolated	5 Shall conform to 8.8 10 000 h 50 years (i.e. x = 50)	Annex C
Long-term flexural strength under dry conditions[d,e], $\sigma_{x, dry}$	Declared value in MPa at 50 years	Composition of test liquid Relative humidity	None (50 ± 10) %	Annex D
Long-term flexural strength under wet conditions[d,e], $\sigma_{x, wet}$	Declared value in MPa at 50 years	Composition of test liquid	Water	Annex D

[a]   It is expected that only one of these methods of creep testing (dry or wet) will be applied, according to national preferences.

[b]   Where it is difficult to acquire a full ring for testing, method 2 provides a practical alternative to method 1.

[c]   To provide a long-term ring stiffness, S_{50}, of not less than 0,125 kPa.

[d]   It is expected that only one of these methods of long-term strength testing (dry or wet or in acid; see Table 7) will be applied, according to national preferences.

[e]   Required for design of non-circular liners.

NOTE 1   Minimum requirements for declared values are provided where these directly relate to minimum design performance characteristics in service. No minimum requirements are provided for material properties that can be compensated by other factors, for example, flexural modulus which combines with wall thickness to provide ring stiffness.

NOTE 2   The dry and wet creep factors referred to in Table 6 are, by definition, the inverse of the creep ratio for thermoplastics liner pipes specified in ISO 11296-1:2018, Clauses 2, 3 and 7. To compare the creep performance of CIPP with that of a thermoplastics liner pipe, an equivalent creep ratio at x years for CIPP can be computed simply as $1/\alpha_x$.

8.6   Physical characteristics

There are no requirements for physical characteristics of the installed lining system.

8.7   Additional characteristics

When tested in accordance with the methods given in Table 7, the resistance of the CIPP to chemical attack under constant deflection (strain corrosion resistance) and its long-term flexural strength under acid conditions (stress corrosion resistance) shall conform to the requirements stated in Table 7.

The test temperature and preconditioning specified in 8.5.1 also apply here.

NOTE   If the carrier material/reinforcement consists entirely of fibres of PET, testing experience indicates that no strain corrosion failure occurs.

Table 7 — Additional characteristics

Characteristic	Requirement	Test parameter		Test method
		Parameter	**Value**	
Resistance to chemical attack in a deflected condition	Minimum extrapolated failure strain at 50 years: declared value but not less than 0,45 %	Composition of test liquid	0,5 mol/l sulfuric acid	ISO 10952
		Number of test pieces	18	
		Test piece length for		
		$d_n \leq 300$ mm	$d_n \pm 5$ %	
		$d_n > 300$ mm	(300 ± 15) mm	
		Test piece diameter	150 mm $\leq d_n \leq 400$ mm	
		Time to which the extrapolated value is to be calculated	50 years	
Long-term flexural strength under acid conditions, $\sigma_{x, acid}$	Declared value in MPa at 50 years	Composition of test liquid	0,5 mol/l sulfuric acid	Annex D
NOTE The relevance of these tests depends on the liner design conditions, but it would normally be expected that only one or the other is carried out.				

8.8   Sampling

Simulated installations used to produce samples for type testing shall be executed in accordance with 9.4.3.

Off-cut samples for installation quality control should preferably be formed by confining an otherwise free section of liner during inflation and cure to the same perimeter as the pipe being lined. As far as possible, such supported samples shall be formed at an intermediate manhole in preference to one or the other end of the overall installation.

Any other method of acquiring non-destructive off-cut samples shall be documented in the installation manual, and supported by test data demonstrating that the relevant characteristics of such samples do not systematically exceed those of samples cut from the actual pipe wall.

Sampling in manholes by use of a confining pipe or sleeve is generally practicable when lining circular pipes of diameter up to 600 mm only. In other circumstances, samples should preferably be taken from the actual pipe wall, and the resulting hole in the liner made good with similar materials by a procedure documented in the installation manual.

Alternative off-cut sampling methods may exceptionally be considered if pipe wall sampling is either not permitted by the client or rendered impractical by site conditions (e.g. where running groundwater prevents satisfactory filling and resealing of the liner after sampling).

For the purposes of the three-point flexural testing in accordance with Table 5 and Annex B, the orientation of samples shall be as follows.

a) For CIPP products in which the mean circumferential and longitudinal flexural properties can be shown by tests on "I" stage pipe samples to differ by no more than ±10 %, either longitudinal or circumferential samples may be used. The sample orientation chosen for type testing shall, however, become the sample orientation requirement for all further flexural testing.

b) For CIPP products of anisotropic wall construction, circumferential samples only shall be used.

In all cases, test pieces shall be placed in the testing machine in such a manner that the inside surface of the CIPP is in contact with the supports and therefore subjected to tension.

NOTE   A ring stiffness calculated from the short-term flexural modulus determined by testing conforming to Annex B and the measured diameter/thickness ratio, d_n/e_m, can differ from the initial specific ring stiffness determined by testing in accordance with ISO 7685, due to material and geometric nonlinearities and differences in testing speed.

9 Installation practice

9.1 Preparatory work

Site preparation required for the installation of specific CIPP lining techniques shall be documented in the installation manual.

NOTE   For general guidance on preparatory work, see ISO 11295.

9.2 Storage, handling and transport of pipe components

Raw materials shall be stored and used in accordance with the recommendation of their respective manufacturers. The liner shall be stored, impregnated and transported under conditions which do not impair performance of the as-installed product in such a way as to prevent conformity to this document.

9.3 Equipment

All technique-specific equipment shall be documented in the installation manual. The items described should include the following, as applicable:

a) resin storage, mixing and impregnation equipment (if impregnation takes place at the installation site).

b) insertion equipment, including

1) the winch and controls for winched-in-place insertion,

2) the inversion collars or elbows for inverted-in-place insertion,

3) the water column, air compressor and/or air/water pressure vessel for inflation or inversion, and

4) the equipment for maintaining and/or monitoring pressure.

c) curing equipment, including

1) a boiler or steam generator,

2) recording equipment for time, temperature and pressure,

3) for light cure systems: UV source, winch for lamp assembly and equipment to record its speed of advance along the pipe, and

4) for electrical cure systems: power supply and associated metering equipment.

d) finishing equipment: manual or robotic cutters and/or grinders for trimming ends and reopening lateral connections.

9.4 Installation

9.4.1 Environmental precautions

The installation manual shall describe any precautions and measures necessary to prevent contaminating the environment, taking into account any provisions in the place of use applicable.

9.4.2 Installation procedures

The procedures for site handling, site impregnation (if applicable), insertion and cure of lining tubes shall be documented in the installation manual.

Where a permanent or semi-permanent membrane is perforated for the purposes of vacuum impregnation of the lining tube, the installation manual shall document the method of patching used to re-seal the membrane.

The maximum longitudinal force that can be applied to the lining tube to prevent excessive stretch or risk of rupture during insertion shall also be documented in the installation manual.

The installer shall further ensure that the pressure in the lining tube during inversion or inflation is sufficient to hold it tight to the pipe wall and prevent any internal deformation of the lining tube, which can be caused by groundwater pressure or the pressure of sewage in laterals.

NOTE   In sewers with running infiltration, a pre-liner or external membrane can be used to prevent contamination of the resin system by water entering the existing pipeline.

The fluid pressure used for inversion or inflation and the rate of insertion of the lining tube shall be continuously monitored during the installation and curing process.

If heating systems are used for curing, the heat source shall be fitted with means for continuously monitoring the temperature of the incoming and outgoing process fluid.

If UV systems are used for curing, the light source shall be fitted with means for continuous monitoring of the speed of advance inside the pipe and on-off status of individual lamps. The lamps should also be checked for radiation intensity at regular intervals, as recommended by the lamp manufacturer.

In all cases, the temperature at points on the interface of the lining tube with the existing pipeline shall be continuously monitored during the curing process by means of sensors located around the invert of the pipe at the downstream end and at other appropriate locations.

All monitored process parameters shall be recorded at intervals of sufficient frequency to capture possible events of short duration, such as pressure surges or peak exothermic temperatures, which can impact the performance of the finished product.

9.4.3   Simulated installations

Given that the processing of CIPP, irrespective of curing system, is sensitive to heat loss to the existing pipeline and surround, the thermal environment of simulated installations used to produce representative samples for type testing shall be controlled.

The thermal environment simulated (i.e. type of existing pipeline, additional insulation or cooling provided, ambient temperature and an estimate of rate of heat loss per unit area from the back of the liner during cure) shall be recorded as an integral part of the type test report.

9.5   Process-related inspection and testing

Process-related inspection and testing shall conform to ISO 11296-1.

9.6   Lining termination

After installation and cure, the CIPP shall be trimmed to re-establish manhole access without disrupting the integrity of the connection to the manhole.

At intermediate manholes, the CIPP lining of the channel may be left in place to provide continuity of invert between the adjacent renovated pipe lengths.

The lining termination shall prevent the cut edge of the composite becoming exposed to either the effluent in the pipe or to groundwater. The lining termination shall not contain any sharp edges that could lead to fouling of the lined pipe with debris.

9.7   Reconnections to existing pipeline system

At entries and exits of manholes, the method of sealing any residual annular space between the CIPP and the existing pipeline to stop infiltration under the maximum design groundwater head shall be documented in the installation manual.

Lateral reconnections may be made from the inside of the main pipe using any class of cured-in-place connection collar, as defined in Clause 6, or from the outside using saddles of materials conforming to 6.1. As an alternative to a class A fitting installed from the inside of the main pipe, a CIPP lateral lining with integral connection seal may be installed from a suitable point of access to the lateral pipe down to the main. In either case, the method of sealing the annulus at lateral connections shall be documented in the installation manual.

The treatment of lateral connections should preferably prevent the cut edge of the composite becoming exposed to either the effluent in the pipe or to groundwater.

9.8   Final inspection and testing

Final inspection and testing shall conform to ISO 11296-1.

9.9   Documentation

The installation parameters recorded shall include the internal fluid pressure applied to the lining tube through all stages of installation and cure and the continuous readings of temperature from all monitoring points during the cure cycle. If applicable, the input of electrical energy to the curing process shall also be recorded.

Annex A
(informative)

CIPP components and their functions

The resin system and carrier material are essential features of the finished pipe. The other components can be present, depending on the specific lining technique used.

The possible functions of CIPP components are given in Table A.1.

Table A.1 — CIPP component functions

Component	Typical process related function	Possible end product ("I" stage) functions						
		Leak tightness	Mechanical resistance		Chemical resistance	Hydraulic smoothness	Abrasion resistance	Jetting resistance
			Stiffness	Strength				
Resin system	None	+	+	+	+a	+a	+a	+a
Carrier material	Carrier for liquid resin	–	b	b	–	–	–	+
Reinforcement	Enhance dimensional stability and strength of the lining tube	–	+	+	–	–	–	+
Temporary internal and/or external membrane	Contain and protect uncured resin system during insertion and curing of the lining tube, removed during or after installation	–	–	–	–	–	–	–
Semi-permanent internal membrane	As temporary membrane, but left in place after curing of resin (not relied on to retain its integrity at the "I" stage)	–	–	–	–	–	–	+
Semi-permanent external membrane		–	–	–	–	–	–	–
Permanent internal membrane	As a semi-permanent membrane, but providing functions for the operational life of the CIPP liner	+	–	–	+	+	+	+
Permanent external membrane		+	–	–	+	–	–	–
a These functions can be provided by an inner resin layer as defined by ISO 10467:—, 4.3.1 a).								
b The carrier material generally affects the properties of the composite, e.g. by either increasing or decreasing mechanical resistance.								

Annex B
(normative)

Cured-in-place pipes — Determination of short-term flexural properties

B.1 General

This annex specifies modifications to the apparatus, test piece shape and dimensions and the test procedure used to allow the determination, in accordance with the principle of the 3-point flexural test of ISO 178, of the flexural properties of "I" stage samples taken from actual or simulated installations of cured-in-place pipes. References are given to the individual clause numbers of ISO 178:2010+A1:2013 modified by this annex.

Reference is also made to ISO 14125:1998+A1:2011 for acceptable ratios of test span to mean specimen thickness applicable to fibre-reinforced thermosetting compounds, and for definitions of failure modes that can occur in long-fibre-reinforced composites.

For curved circumferential samples, modified formulae including geometric correction factors are provided for calculating values of flexural modulus, stress and strain from load and deflection measurements determined in accordance with ISO 178 or ISO 14125. These and the reporting requirements applicable to 3-point flexural testing are documented in full.

B.2 Apparatus

For testing of curved circumferential samples, both supports, as well as the loading edge defined in ISO 178:2010+A1:2013, 5.3, shall be of cylindrical or semi-cylindrical shape with radius (5 ± 0,2) mm (see Figure B.1).

In order to reduce the imposition of torsional strains as test pieces, which are not completely flat, are brought into full contact with the supports, the striking edge shall be free to rotate in a plane perpendicular to the axis of the sample.

In all other respects, the test machine, force and deflection measuring systems, and equipment for measuring specimen width and thickness shall comply with the requirements of either ISO 178 or ISO 14125.

B.3 Test piece shape and dimensions

NOTE   The following requirements modify or supplement those of ISO 178: 2010+A1:2013, 6.1 and 6.2.

B.3.1 Shape

Test pieces cut from the circumferential direction of a cured-in-place pipe shall have substantially uniform radius of curvature, such that when the test piece is placed on the supports, the highest point occurs at a point along the span which is not more than 0,1 L from the centre (see Figure B.1).

The edges of longitudinal test pieces shall be cut parallel to each other (see Figure B.2).

B.3.2 Thickness

The composite thickness within the central third of the length of any individual test piece shall nowhere deviate from its mean value by more than 10 %.

B.3.3 Width

The width of circumferential direction test pieces shall generally be (50 ± 1) mm, if cut from cylindrical pipe, or conform to Table B.1, if cut from flat samples. For composites using coarse reinforcements or if the principal orientation of the reinforcement is not in the circumferential direction, a greater value of test piece width may be declared in either or both cases. These declared values of test piece width, with tolerance ±1 mm, shall then become the requirement for all circumferential direction flexural testing of the product concerned on curved and flat samples respectively.

The width of longitudinal test pieces shall be in accordance with Table B.1.

NOTE   If the width of a longitudinal test piece exceeds that specified in Table B.1 for any reason, it can be necessary to correct for the enhanced second moment of area of the curved cross-section (see Figure B.2) in the derivation of flexural properties.

Table B.1 — Values for longitudinal test piece width, b, in relation to mean wall thickness, $e_{c,m}$

Dimension in millimetres

Mean composite thickness $e_{c,m}$	Width b
$e_{c,m} \leq 10$	15,0 ± 1
$10 < e_{c,m} \leq 20$	30,0 ± 1
$20 < e_{c,m} \leq 35$	50,0 ± 1
$e_{c,m} > 35$	80,0 ± 1

B.3.4 Length

Flat test pieces to be tested with nominal span, L, shall be cut to a total length of not less than $L + 4\,e_{c,m}$, except in the case of unidirectional or multidirectional composites conforming to Class III or Class IV as defined by ISO 14125:1998+A1:2011, Table 3, for which the test piece length shall not be less than $L + 10\,e_{c,m}$.

For curved test pieces, the same multiples of composite thickness shall apply to the specimen length to be provided in excess of the test span, except that this excess length shall be measured along the arc of the specimen in the circumferential direction. The total chord length, L_3, as defined by Figure B.1, to which the test piece shall be cut, will thus generally be given by $L_3 = L_2 + 4\,e_{c,m}\cos\phi$, or in the case of Class III or Class IV, composites, by $L_3 = L_2 + 10\,e_{c,m}\cos\phi$.

B.4 Procedure

NOTE   The following requirements modify or supplement those of ISO 178:2010+A1:2013, 8.1, 8.2 and 8.3.

B.4.1 Measurement of composite thickness and width

The total thickness, h, shall first be determined by measuring the test piece at six points within the central third of its span (see Figure B.3), in accordance with ISO 3126. The composite thickness is then determined by subtracting from each measurement of total thickness, the known or separately measured thicknesses of any internal and/or external membranes.

NOTE   The thickness of any permanent or semi-permanent membrane can generally be assigned its value declared in accordance with 8.4.2.

Any excess neat resin on the back of the test piece (corresponding to the outside of the liner pipe), especially if forming a layer of irregular thickness, may be partially or wholly ground off prior to testing, in order to comply with thickness tolerances or to reduce associated error in the measurement of flexural modulus, provided that no part of the intended composite is thereby removed. Excess neat resin in this context is defined as cured resin not incorporating any fibres, and which, as a consequence

of a site sampling technique or otherwise, locally increases the ratio of resin to fibres in the composite from that declared in accordance with 8.4.2.

Resin-rich layers including any abrasion layer which are a deliberate part of the CIPP wall structure shall not be deducted from composite thickness or ground off prior to testing.

If any individual composite thickness measurement deviates by more than 10 % from the mean composite thickness, $e_{c,m}$, the test piece shall be discarded and a new test piece chosen at random.

If the mean value of composite thickness, $e_{c,m}$, of any individual test piece deviates by more than 10 % from the mean, $\overline{e}_{c,m}$, of the means for a set of test pieces, that test piece shall likewise be replaced by another test piece chosen at random.

The width of the test piece shall be measured at the locations of the three pairs of points used for thickness measurement (see Figure B.3).

B.4.2   Setting of span

The nominal distance, L, between supports shall be set to $(16 \pm 1)\, e_{c,m}$, except in the case of unidirectional or multidirectional composites conforming to Class III or Class IV as defined by ISO 14125:1998+A1: 2011, Table 3, for which a span calculated on a higher ratio of $L/e_{c,m}$ shall be applied as necessary to avoid failures initiated by interlaminar shear (see ISO 14125:1998+A1:2011, Figure 6).

Where a curved test piece is used, the half-angle, ϕ, between its points of contact with the supports, as defined by Figure B.1, shall not exceed 45°. This corresponds to an upper limit on the nominal span to diameter ratio, L/d_n, of approximately 0,70.

B.4.3   Measurement of span

The horizontal distance, L, between the centres of the supports shall be measured to the nearest 0,5 %.

Where curved samples are used, the true span, L_2, as defined by Figure B.1, shall be derived from Formula (B.1):

$$L_2 = \frac{L}{1 - \left[\dfrac{r + e_1 + \left(e_{c,m} / 2 \right)}{R_2} \right]} \tag{B.1}$$

where

r is the radius of the supports;

$e_{c,m}$ is the mean composite thickness;

e_1 is the mean thickness of any internal membrane;

R_2 is the radius of curvature of the test piece at mid-thickness of the composite.

In the case of circumferential test pieces cut from circular liner pipe of known outside diameter, d_n, R_2 may simply be assigned the value shown in Formula (B.2):

$$R_2 = \frac{d_n - e_{c,m}}{2} \tag{B.2}$$

In all other cases, R_2 shall be determined either

a)   by calculation as Formula (B.3):

$$R_2 = \frac{V}{2} + \frac{L_1{}^2}{8V} + e_1 + \frac{e_{c,m}}{2} \tag{B.3}$$

where the values of dimensions, V and L_1, as defined by Figure B.1, are obtained by direct measurement of the test piece when placed unloaded on the supports, or

b) by tracing the edge profile of the inside surface of the test piece onto paper, and using geometric construction or other suitable means to derive the radius, R_1, of the circular arc which best fits that profile, as shown in Formula (B.4):

$$R_2 = R_1 + e_1 + \frac{e_{c,m}}{2} \tag{B.4}$$

B.4.4 Alignment of test piece

Prior to loading, the test piece shall be aligned perpendicular to the supports and positioned such that its centreline lies within ± 0,5 mm of the line of action of the pivot point of the striking edge.

B.5 Calculation and expression of results

NOTE   The following requirements modify or supplement those of ISO 178:2010+A1:2013, 9.1, 9.2 and 9.3.

B.5.1 Span and thickness for calculation

Where curved samples are used, the span for calculation of flexural properties shall be L_2, as defined by Formula (B.1), rather than the distance, L, between the centres of the supports. The thickness for calculation of composite flexural modulus and strength shall, in all cases, be the mean composite thickness, $e_{c,m}$, measured in accordance with B.4.1.

B.5.2 Determination of strain datum

The datum or zero point for strain measurement shall be established from the point of intersection of the slope of the initial linear portion of the apparent stress-strain curve with the strain axis (see Figure B.4). Where the testing machine software does not automatically correct for zero errors, the procedure described in B.5.3 for deriving the apparent flexural modulus from uncorrected strain data shall also be used to derive the true strain datum.

B.5.3 Derivation of flexural properties for flat samples

For flat samples cut in the axial direction, the calculation of stress, strain and modulus shall be in accordance with ISO 178:2010+A1:2013, Formulae (5) to (9), but with the substitution of mean composite thickness, $e_{c,m}$, for total thickness, h, in accordance with B.5.1.

When using uncorrected strain data, the short-term flexural modulus, E_0, shall be determined by the procedure in ISO 178:2010+A1:2013, 9.3, using the value of $\varepsilon_{f2} = \varepsilon_{f1} + 0,002$, where ε_{f1} is assigned the value between 0,000 5 and 0,004 which maximizes the value of the calculated flexural modulus, $E_f = E_0$. By extrapolating the line of slope, E_0, thus constructed to the strain axis, the datum strain, ε_{f0}, may be determined (see Figure B.4). The true strain at any point on the stress-strain curve is then determined from the uncorrected strain as (ε_{f1})corrected = (ε_{f1})uncorrected − ε_{f0}. If, due to excessive twist in its shape or otherwise, the test piece has not yet fully engaged the supports before an apparent (uncorrected) strain of 0,002 has been reached, the test piece shall be discarded and a new test piece chosen at random.

B.5.4 Derivation of flexural properties for curved samples

For curved samples cut in the circumferential direction, calculations shall first be conducted as for flat samples, with the additional substitution of L_2 for L as instructed by B.5.1, resulting in the following formulae for apparent flexural stress, σ_c, [see Formula (B.5)] and strain, ε_c [see Formula (B.6)]:

$$\sigma_c = \frac{3F \cdot L_2}{2b \cdot \left(e_{c,m}\right)^2} \tag{B.5}$$

$$\varepsilon_c = \frac{6s \cdot e_{c,m}}{\left(L_2\right)^2} \tag{B.6}$$

Then, calculate the apparent modulus, E_c, from the difference in apparent stress divided by the difference in apparent strain at nominal reference strains of 0,000 5 and 0,002 5 as shown in Formula (B.7):

$$E_c = \frac{\sigma_{c2} - \sigma_{c1}}{\varepsilon_{c2} - \varepsilon_{c1}} \tag{B.7}$$

where the higher subscript value (2) applies to the higher measured values of apparent stress and strain and the lower subscript value (1) to the lower measured values of apparent stress and strain.

When using uncorrected strain data, apply a similar procedure to that described in B.5.3. Set value of $\varepsilon_{c2} = \varepsilon_{c1} + 0,002$, where ε_{c1} is assigned the value between 0,000 5 and 0,004 which maximizes the value of the calculated apparent flexural modulus, E_c, and then extrapolate the line of slope, E_c, to the strain axis to determine the datum strain, ε_{c0}.

The apparent values of modulus and stress are then corrected for the effects of curved specimen geometry using Formula (B.8):

$$E_f = \frac{E_c}{C_E} \tag{B.8}$$

where C_E is the correction factor to convert apparent modulus obtained from a curved specimen, E_c, to the flexural modulus that would be obtained from an equivalent flat specimen, E_f, using Formula (B.9):

$$C_E = \frac{\left(L_2 / d_m\right)^3 \cdot \cos^2 \phi}{1,5 \cdot \left[\phi - \left(L_2 / d_m\right) \cdot \cos\phi\right]} \tag{B.9}$$

where the mean pipe diameter, $d_m = 2R_2$,

and Formula (B.10):

$$\sigma_f = \frac{\sigma_c}{C_\sigma} \tag{B.10}$$

where C_σ is the correction factor to convert apparent stress or strength obtained from a curved specimen, σ_c, to the equivalent for a flat specimen, σ_f, using Formula (B.11):

$$C_\sigma = \left[1 + \frac{e_{c,m}}{3\,d_m}\right] / \cos\phi \tag{B.11}$$

NOTE 1 ϕ can be calculated from the formula, $\sin\phi = L_2 / d_m$.

It is important that curved specimens are tested within the limits specified in B.4.2 for both span to thickness ratio and span to diameter ratio.

NOTE 2   No correction is made for flattening of specimens during the course of testing, but if necessary, this can be considered using the guidance of ISO 14125:1998+A1:2011, Annex B.

B.5.5 Alternative expression of flexural properties

Where the mean composite thickness, $e_{c,m}$, cannot easily be determined, for example, due to uncertainty about thickness of membranes or any excess neat resin layer, Formulae (B.5) and (B.6), may be computed using mean total test piece thickness, h_m, instead of $e_{c,m}$.

The results shall, in that case, be expressed as the section bending stiffness as shown in Formula (B.12):

$$EI = \frac{E_f \cdot b \cdot h_m^3}{12} \tag{B.12}$$

and the section moment capacity as shown in Formula (B.13):

$$M = \frac{\sigma_f \cdot b \cdot h_m^2}{6} \tag{B.13}$$

NOTE   This alternative expression of the test results can be useful for quality control testing of samples of installed CIPP liners to verify attainment of section design characteristics, without the need for detailed examination or measurement of wall structure.

B.6 Test report

The test report shall include the following information:

a)   a reference to this document, i.e. ISO 11296-4;

b)   a complete identification of the material tested, including type, source, manufacturer's code number, form and previous history, and composite class, where these are known;

c)   for pipe samples, the orientation of each test piece (i.e. circumferential or longitudinal);

d)   the shape and dimensions of each test specimen, including, in the case of curved specimens, the mean total thickness, h_m, the total length, L_3, the value and method of determination of radius, R_2, and, where directly measured, the dimensions, L_1 and V;

e)   the thicknesses, e_1 and e_2, of any internal and/or external membranes deducted from the measured total thickness to determine the composite thickness in accordance with B.4.1;

f)   the mean composite thickness, $e_{c,m}$, and the maximum percentage deviation from the mean in the middle third of the test piece;

g)   the date of measurement;

h)   the method of preparing the specimens;

i)   the test conditions and conditioning procedures, if applicable;

j)   the number of specimens tested;

k)   the nominal length, L, of the span used, and in the case of curved specimens, the calculated true span, L_2;

l)   the speed of testing;

m)   the accuracy grading of the test machine in accordance with either ISO 178:2010+A1:2013, 5.1 or ISO 14125:1998+A1:2011, 5.1.1;

n)   in the case of flat specimens, the face of the specimen in contact with the supports;

o)   the thickness, e_1, of any membrane in contact with the supports and how determined;

p) the formulae and the strain range (i.e. strain difference) used;

q) the test results, expressed as the mean values of modulus, stress and strain at first break, and stress and strain at maximum applied load, or alternatively, where specified by the client as corresponding values of section bending stiffness and moment capacity, with date of testing;

r) the individual measurements, including force-displacement diagrams, and the values of force and displacement corresponding to all key points illustrated in Figure B.4 a);

s) the type(s) of failure obtained;

t) the standard deviation of the mean values, if required.
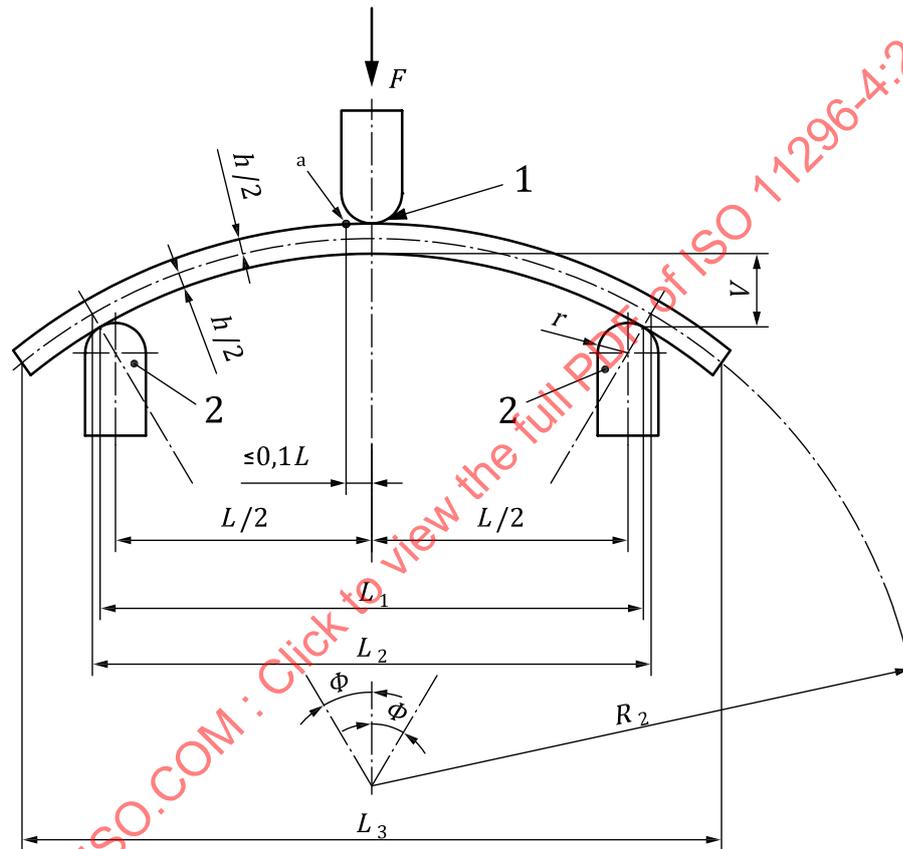
Key

1　striking edge

2　support

F　applied force

h　total thickness of test piece

L　distance between supports

L_1　distance between points of contact of the unloaded test piece with the supports

L_2　true span of curved test piece

L_3　total chord length of curved test piece

r　radius of support

R_2　radius of curvature of test piece at mid-thickness

V　rise of the centre of the unloaded test piece above its points of contact with the supports

ϕ　half-angle of arc of unloaded test piece between its points of contact with the supports
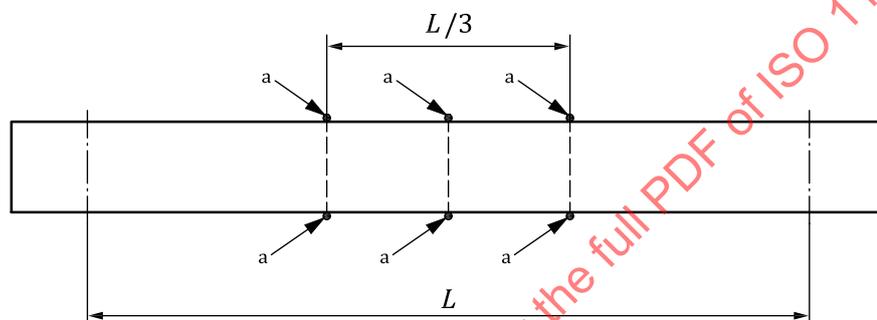
a　High point of the test piece.

Figure B.1 — Dimensions of curved circumferential test piece in position at the start of the test
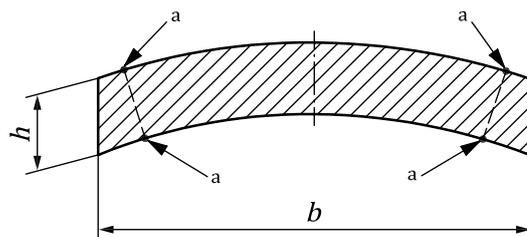
Key

h   thickness of test piece
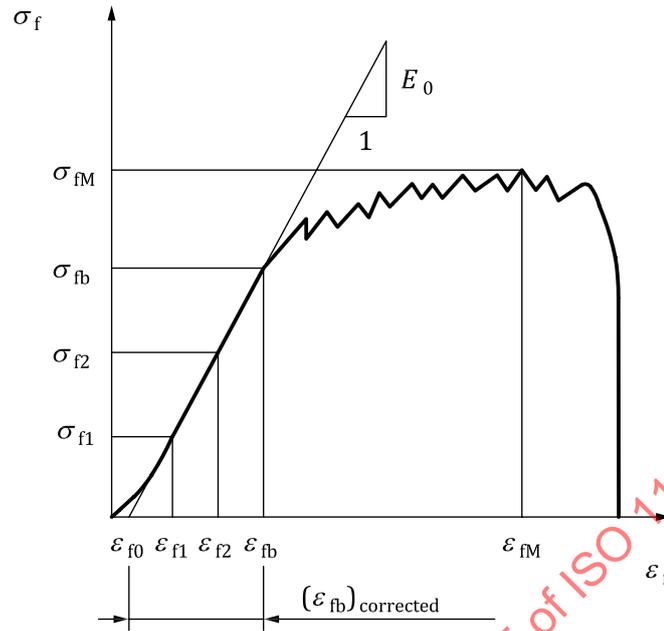
b   width of test piece

a   Measuring point.

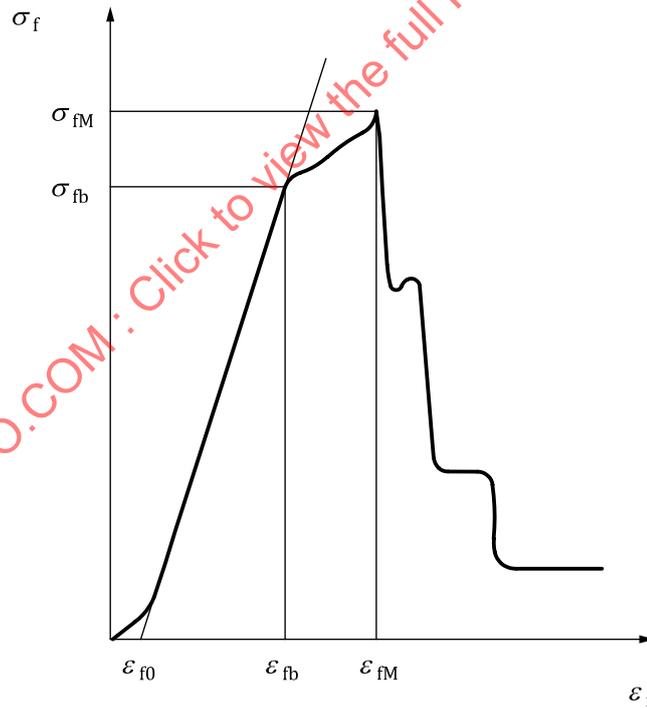**Figure B.2 — Cross-sectional shape of longitudinal test piece showing points for measurement of thickness**

Key

a   Measuring point.

Figure B.3 — Plan view of test piece (circumferential or longitudinal) showing points for measurement of thickness and width

a) Composite with extensive strain capacity between first break and maximum applied load

b) Composite exhibiting brittle rupture at or soon after first break

Figure B.4 — Features of typical flexural stress-strain curves and associated derivation of material properties

Annex C
(normative)

Cured-in-place pipes — Determination of long-term flexural modulus under dry or wet conditions

C.1 General

This annex specifies a method for determining the long-term flexural modulus of CIPP material subjected to a constant flexural stress under dry or wet conditions. The specified test period is 10 000 h, and the result of the test is expressed as a value of long-term modulus extrapolated to 50 years. The method of extrapolation used also, however, allows determination of long-term modulus at any other time between 10 000 h and 50 years.

C.2 Principle

A test piece cut from a pipe sample of CIPP is subjected to three-point bending under constant load, under conditions of controlled temperature. In the case of dry testing, the relative humidity of the atmosphere is also controlled, or in the case of wet testing, the test piece is immersed in water. The deformation, which increases over time, is measured and the apparent flexural modulus, which correspondingly decreases, is calculated. The modulus values are plotted against time and the modulus at 50 years or other specified design life is obtained by extrapolation.

C.3 Apparatus

The apparatus shall conform to that specified in ISO 899-2, but with supports of cylindrical or semi-cylindrical shape in accordance with B.2, and for wet testing with the addition of the following.

C.3.1 A water bath or similar equipment, which

a) maintains the test piece immersed in potable tap water,

b) maintains the water temperature at (23 ± 2) °C, and

c) is adequately covered to avoid rapid loss of water due to evaporation.

NOTE   Encapsulating the sample in a loose-fitting, water-filled and sealed bag of flexible plastic film is an acceptable means of achieving a) and c).

C.4 Sample preparation

Samples shall be taken from actual or simulated installations in accordance with 8.8 and 9.4.3.

C.5 Preparation of test pieces

At least five test pieces shall be cut from the full thickness of the liner sample, oriented in either the circumferential or longitudinal direction according to the criteria of 8.8 and with dimensions and tolerances as specified in B.3. In the case of circumferential test pieces, the curvature of the sample selected for long-term testing shall be limited to provide test pieces with a true span to mean diameter ratio, $L_2/d_m \leq 0,28$.