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**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 matières plastiques pour la rénovation
des réseaux d'assainissement gravitaires enterrés —*

Partie 4: Tubage continu par tubes polymérisés sur place

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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.

ISO 11296-4 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*.

ISO 11296 consists of the following parts, under the general title *Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks*:

- *Part 1: General*
- *Part 3: Lining with close-fit pipes*
- *Part 4: Lining with cured-in-place pipes*

Lining with continuous pipes is to form the subject of a part 2, lining with discrete pipes is to form the subject of a part 5 and lining with spirally-wound pipes is to form the subject of a part 7.

This corrected version of ISO 11296-4:2009 incorporates the replacement of "ISO 178" with "ISO 178 as modified by Annex B" in the fourth row and fifth column of Table 5.

Introduction

The System Standard, of which this is part 4, specifies the requirements for plastics piping systems of various materials used for renovation of existing pipelines in a specified application area. System Standards for renovation specify procedures for the following applications:

- plastics piping systems for renovation of underground non-pressure drainage and sewerage networks;
- plastics piping systems for renovation of underground drainage and sewerage networks under pressure;
- plastics piping systems for renovation of underground water supply networks;
- 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.

Each of the System Standards comprises a part 1 (general) and all applicable renovation technique family-related parts from the following:

- 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.

The requirements for any given renovation technique family are given in part 1, applied in conjunction with the other relevant part. For example, parts 1 and 2 specify the requirements relating to lining with continuous 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 gives the common structure and the relationship between ISO 11296 and the System Standards for other application areas.

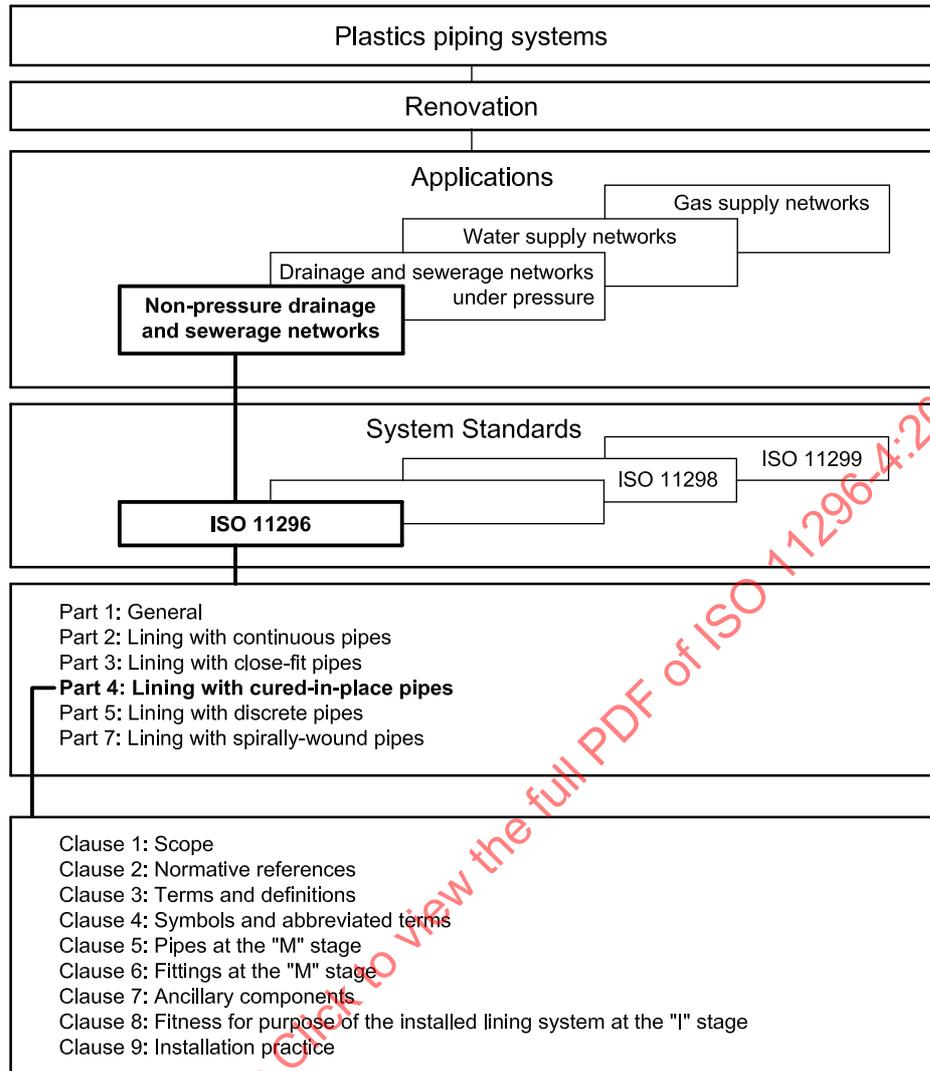


Figure 1 — Format of the renovation System Standards

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

Part 4: Lining with cured-in-place pipes

1 Scope

This part of ISO 11296, 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.

It applies to the use of various thermosetting resin systems, in combination with compatible fibrous carrier materials and other process-related plastics components (see 5.1).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 178:2001, *Plastics — Determination of flexural properties*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

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

ISO 8513, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of longitudinal tensile properties*

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

ISO 10928¹⁾, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Methods for regression analysis and their use*

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:—²⁾, *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 25780:—³⁾, *Plastics piping systems for pressure and non-pressure water supply, irrigation, drainage or sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin — Pipes with flexible joints intended to be installed using jacking techniques*

EN 14364:2006, *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.

3.1 General terms

3.1.1

carrier material

porous component of the liner, which carries the liquid resin system during insertion into the pipe being renovated and forms part of the installed lining system once the resin has been cured

3.1.2

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 and installed by a specific process

3.1.3

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

3.1.4

close-fit

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

3.1.5

composite

combination of cured resin system, carrier material and/or reinforcement, excluding any internal or external membranes or any layer of excess neat resin

1) To be published.

2) To be published.

3) To be published.

3.1.6**first break**

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

3.1.7**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, as determined by structural design

3.1.9**internal membrane**

membrane forming the inside surface of the pipe after installation

3.1.10**external membrane**

membrane forming the outside surface of the pipe after installation

3.1.11**lateral connection collar**

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

3.1.12**lining tube**

flexible tube, consisting of carrier material, resin system and any membranes and/or reinforcement, as combined prior to insertion in the pipe to be lined

3.1.13**nominal thickness**

one of a range of discrete liner wall thicknesses dictated by the materials used for liner construction and chosen so as to result in a finished wall thickness of the composite not less than the design thickness

3.1.14**preliner**

external membrane which is installed separately and before the resin-impregnated liner

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

NOTE The reinforcement can be incorporated in the carrier material, constitute the carrier material, or can be a separate layer.

3.1.16**resin system**

thermosetting resin including the curing agent(s) and any fillers or other additives, in specified proportions

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 liner is introduced by inversion to achieve simultaneous insertion and inflation

3.2.3

winched-in-place insertion

method whereby the flat impregnated liner is first pulled into the pipe to be lined and then inflated to bring it up to size

NOTE Inflation can be achieved by means of a separate pressurized tube or hose inside the liner which is either withdrawn after resin cure or left in place as a permanent internal membrane.

3.2.4

temporary membrane

internal membrane, used to separate process fluid (typically water or air) from the resin system during liner insertion, which is withdrawn after resin cure

4 Symbols and abbreviated terms

The symbols and abbreviated terms given in ISO 11296-1 and the following apply.

4.1 Symbols

b	width of test piece
E_0	short-term flexural modulus
E_x	long-term flexural modulus at x years
E_t	flexural creep modulus at time t
F	force applied in flexural test
h	thickness of test piece
h_m	mean thickness of 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 curved flexural test piece
r	radius of support
R_2	radius of curvature of test piece at mid-thickness
V	rise of centre of curved flexural test piece above its points of contact with supports
S_0	initial specific ring stiffness
δ_t	deflection of flexural test piece at time t
$\alpha_{x, \text{dry}}$	dry creep factor at x years

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_{fb}	flexural stress at first break
σ_{fM}	flexural stress at maximum applied load
σ_l	ultimate longitudinal tensile stress

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)
PP	Polypropylene
PUR	Polyurethane
PVC-U	Unplasticized poly(vinyl chloride)
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). For requirements for the cured composite, see Clause 8.

5.1 Materials

Lining tubes shall comprise at least the following components:

- resin system;
- carrier material.

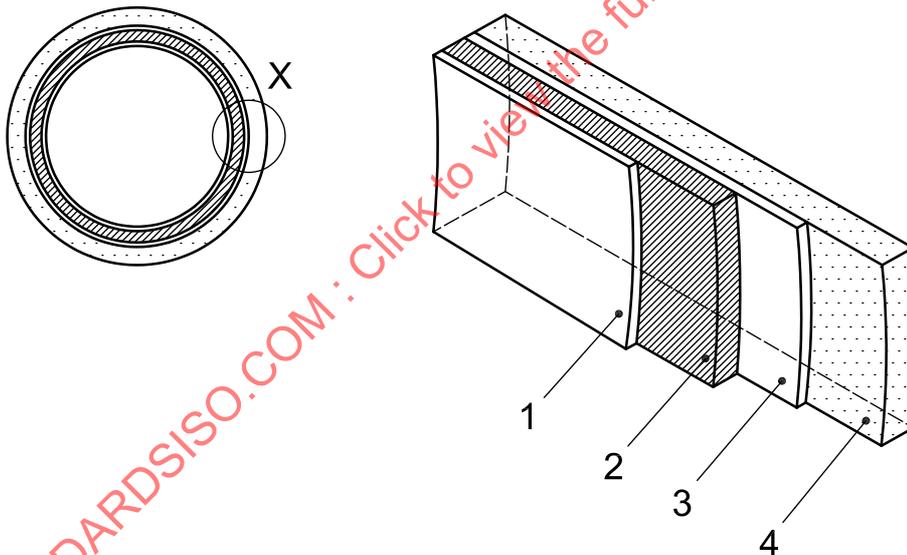
In addition, they may optionally comprise:

- reinforcement;
- internal membrane or temporary membrane;
- external membrane.

For the relationship between these components, see Figure 2.

NOTE 1 Various components can have 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 or temporary membrane
- 2 composite (resin in carrier material/reinforcement)
- 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 — Classification of lining tube components by their material

Lining tube component	Materials
Resin system: — resin type — filler type — curing system	UP, VE or EP None, inorganic or organic Heat-initiated, light-initiated or ambient cure
Carrier material/reinforcement	Polymeric fibres: PA, PAN, PEN, PET or PP Glass fibres conforming to ISO 25780:—, 4.2.2 Carbon fibres of declared designation conforming to ISO 13002 Combinations of the above fibres ^a
Membranes (internal, external or temporary)	Unrestricted ^b
^a Where a combination of fibres is used, the proportions by mass of each fibre type shall be declared to within 5 %.	
^b As there are no requirements for membranes, there are also no restrictions on the choice of 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	
Flexural stress at first break	For UP and VE: ≥ 100 MPa For EP: ≥ 80 MPa	Speed of testing	2 mm/min	ISO 178:2001
		Number of test pieces	3	
		Dimensions of test piece: thickness h width b	$3 \leq h \leq 6$ mm ($15 \pm 0,5$) mm	
Tensile elongation at break	For UP and VE: ≥ 2 % For EP: $\geq 2,5$ %	Speed of testing	5 mm/min	ISO 527-2
		Number of test pieces	3	
		Test piece shape and initial gauge length	Specimen type 1B	
Temperature of deflection under load	For UP and VE: ≥ 85 °C For EP: ≥ 70 °C	Orientation of test piece	Edgewise	Method A of ISO 75-2
		Number of test pieces	3	

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

No mechanical requirements apply at the "M" stage.

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:—, 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.

As specified in ISO 11296-1:—, 5.8 c), the dimensions 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.

As specified in ISO 11296-1:—, 5.8 d), the dimension marked shall be the wall thickness.

As specified in ISO 11296-1:—, 5.8 f), the manufacturer's information shall enable identification of the lining tube structure and (if pre-impregnated) the resin system used.

6 Fittings at the "M" stage

NOTE 1 This clause describes the various materials which a cured-in-place fitting conforming to this part of ISO 11296 can comprise, and specifies requirements relating to those materials and intermediate fabrications at the "M" stage.

NOTE 2 Since by definition a cured-in-place pipe is partly manufactured on site, requirements of the finished product can only be verified at the "I" stage. For "I" stage requirements, see Clause 8.

NOTE 3 The only cured-in-place fittings covered by this part of ISO 11296 are lateral connections 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.

6.1 Materials

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 14364:2006, 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

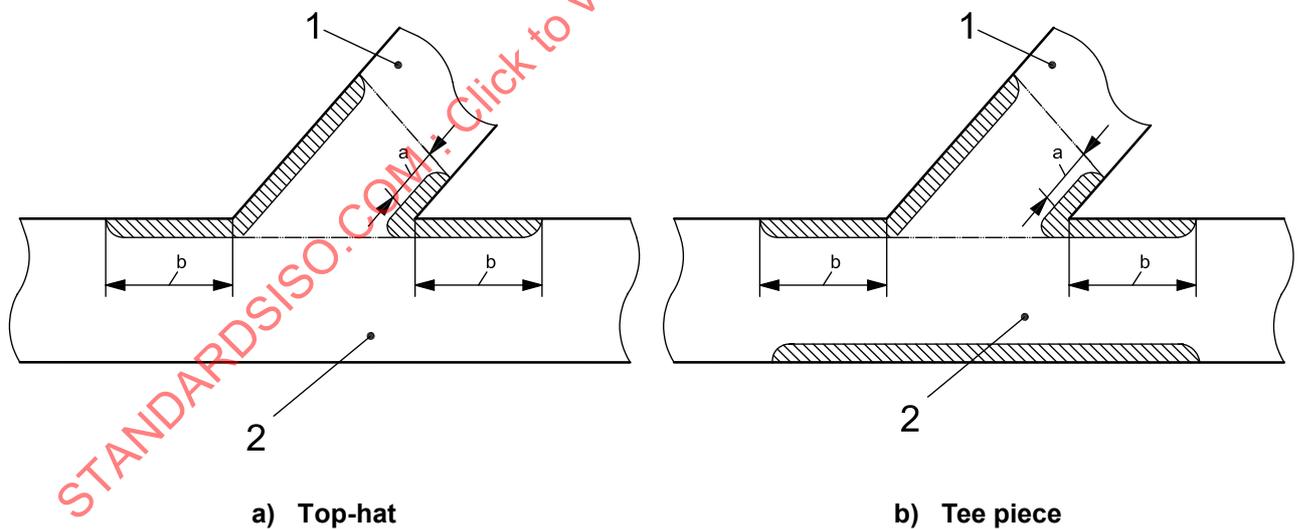
Cured-in-place lateral connection collars shall be classified, as indicated in Table 3, according to the minimum distance extended into the lateral pipe.

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

Class	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

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).

To avoid obstructions to flow and maintenance equipment, the transitions between the collar and both main and lateral pipes should be smooth.



Key

- 1 lateral pipe
- 2 main pipe
- a Extension of collar.
- 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:—, 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:—, 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:—, 6.8 d), the dimension marked shall be the nominal wall thickness.

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

7 Ancillary components

This part of ISO 11296 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 material components selected from the ranges defined in 5.1 and 6.1.

NOTE This part of ISO 11296 does not specify requirements for any end-product functions of internal membranes (see Annex B).

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 host pipe, which exceed 2 % of the nominal diameter or 6 mm, whichever is the 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 host pipe. At bends and at irregularities in the host pipe, 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

NOTE When assessing minimum free bore attainable after CIPP installation at bends, changes of cross-section or stepped joints in the existing pipe, the likelihood of local folding can be taken into account (see 8.2).

8.4.1 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 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.

8.4.2 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_m , of the composite	Not less than the design thickness	ISO 7685 (ring test pieces, see Table 5) or B.4.1 (flexural test pieces)
Minimum wall thickness, e_{min} , of the composite	Not less than 80 % of the design thickness, or 3 mm, whichever is the greater ^a	
^a The e_{min} requirement does not apply to points where local wall thickness reduction is caused by irregularity in the host pipe.		

8.5 Mechanical characteristics

When tested in accordance with the methods given in Table 5, the mechanical characteristics of pipe samples taken from actual or simulated installations in accordance with 8.8 shall conform to this table.

NOTE The dry creep factor referred to in Table 5 is the inverse of the creep ratio for thermoplastics liner pipes defined in ISO 11296-3. 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 $1/(\alpha_{x, dry})$.

Table 5 — Mechanical characteristics of pipes

Characteristic	Requirement	Test parameters		Test method
		Parameter	Value	
Initial specific ring stiffness, S_0	Declared value, but not less than the greater of 0,25 kPa or $(0,125/\alpha_{50, \text{dry}})$ kPa	Number of test pieces Test piece length for: $d_n \leq 300$ mm $d_n > 300$ mm Temperature For method B: relative deflection	2 d_n mm \pm 5 % 300 mm \pm 5 % (23 \pm 2) °C (3 \pm 0,5) %	Method A or ^a Method B of ISO 7685
Dry creep factor ^b , $\alpha_{x, \text{dry}}$	Declared value but not less than 0,2	Method 1 (ring test) ^c — number of test pieces — test piece length for: $d_n \leq 300$ mm $d_n > 300$ mm — test period — time to which values are to be extrapolated — temperature — relative humidity	2 d_n mm \pm 5 % 300 mm \pm 5 % 10 000 h 50 years (23 \pm 2) °C (50 \pm 5) %	ISO 7684
		Method 2 (3-point flexural test) ^c — number of test pieces — sample orientation — test period — time to which values are to be extrapolated — temperature — relative humidity	5 Shall conform to 8.8 10 000 h 50 years (i.e. $x = 50$) (23 \pm 2) °C (50 \pm 5) %	Annex D
Short-term flexural modulus, E_0	Declared value but not less than 1 500 MPa	Number of test pieces Speed of testing	5 10 mm/min	ISO 178 as modified by Annex B
Flexural stress at first break, σ_{fb}	Declared value but not less than 25 MPa	Sample orientation	Shall conform to 8.8	
Flexural strain at first break, ε_{fb}	Declared value but not less than 0,75 %	Temperature	(23 \pm 2) °C	
Long-term flexural modulus under wet conditions ^b , $E_{x, \text{wet}}$	Declared value but not less than 300 MPa at 50 years	Number of test pieces	5	Annex C
Ultimate longitudinal tensile stress, σ_l	Declared value but not less than 15 MPa	Temperature	(23 \pm 2) °C	Method A or ^a Method B of ISO 8513
Ultimate elongation	Declared value but not less than 0,5 %	Number of test pieces Speed of testing	5 5 mm/min	
^a In case of dispute, Method A applies. ^b It is expected that only one of these methods of creep testing (dry or wet) will be applied, according to national preferences. ^c Where it is difficult to acquire a full ring for testing, Method 2 provides a practical alternative.				

8.6 Physical characteristics

No physical requirements apply.

8.7 Additional characteristics

When tested in accordance with the method given in Table 6, the resistance of the CIPP to chemical attack under constant deflection (strain corrosion resistance) shall conform to the requirement stated in the table.

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

Table 6 — 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: $\geq 0,45\%$	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 mm $\pm 5\%$	
		$d_n > 300$ mm	300 mm $\pm 5\%$	
		Test piece diameter	$150 \leq d_n \leq 400$	
		Test temperature	(23 \pm 2) °C	
Time to which the extrapolated value is to be calculated	50 years			

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 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 three-point flexural testing conforming to ISO 178, in accordance with Table 5 and Annex B, the orientation of samples shall be as follows:

- a) For CIPP products in which the mean hoop and longitudinal flexural properties can be shown by tests on flat plates to differ by no more than $\pm 10\%$, either longitudinal or hoop 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, hoop 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 ISO 178 and the measured diameter/thickness ratio, d_n/e_m , does not generally equate to the initial specific ring stiffness determined by testing in accordance with ISO 7685, due to material and geometric non-linearities.

9 Installation practice

9.1 Preparatory work

For the preparatory work, ISO 11296-1 applies.

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 part of ISO 11296.

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) winch and controls for winched-in-place insertion;
 - 2) inversion collars or elbows for inverted-in-place insertion;
 - 3) water column, air compressor and/or air/water pressure vessel for inflation or inversion;
 - 4) equipment for maintaining and/or monitoring pressure.
- c) Curing equipment, including:
 - 1) 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;
 - 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 measures necessary to prevent liquid resin from contaminating the environment and to reduce the accumulation of volatile materials in the atmosphere. If hot processing fluids are used, they shall not be disposed of into the sewerage network at temperatures and/or release rates which could cause damage.

Any local regulations specifying maximum fluid release temperatures should be taken into account.

Any lubricant used to reduce friction during installation shall be declared. The installation manual shall describe any precautions necessary to prevent possible adverse effects of such lubricant on the CIPP or the environment.

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.

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 sewerage in laterals.

NOTE In sewers with running infiltration, a pre-liner or integral 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, or in the case of electric heating systems, the electric power input.

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 host pipe, 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 11296-1:2009, 9.5.

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.

9.7 Reconnecting to existing manholes and laterals

At entries and exits from manholes, any residual annular space between the CIPP and the existing pipeline shall be sealed using a swelling rubber ring built in behind the liner and/or a compatible polymeric grout capable of resisting the maximum anticipated groundwater pressure in the annulus. The system supplier shall demonstrate that the unrestrained saturated thickness of any swelling rubber ring is sufficient to close the expected annular space with adequate sealing compression. It shall further be demonstrated that the longitudinal restraint of the rubber ring is sufficient to prevent it extruding from the annular space when swollen.

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.

9.8 Final inspection and testing

Final inspection and testing shall conform to ISO 11296-1:2009, 9.8.

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 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 matrix/coating material		+	+				+
Internal membrane	Separate resin from fluid used for inversion/inflation and curing	+			+	+	+	
Temporary membrane	As internal membrane, but removed after curing of resin							
External membrane	Contain liquid resin and prevent contamination of or wash out by groundwater							

^a These functions can be provided by a resin layer as defined in ISO 25780:—, 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 — Modifications to ISO 178 for flexural testing

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 ISO 178, of the flexural properties of samples taken from actual or simulated installations of cured-in-place pipes. References are given to the individual clause numbers of ISO 178:2001 modified by this annex. In all other respects, the provisions of ISO 178 remain applicable.

B.2 Apparatus

If curved hoop samples are tested, both supports, as well as the loading edge defined in ISO 178:2001, 5.3, shall be of cylindrical or semi-cylindrical shape with radius $(5 \pm 0,1)$ 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.

B.3 Test piece shape and dimensions

NOTE The following requirements modify or supplement those of ISO 178:2001, 6.1 and 6.2.

B.3.1 Shape

Test pieces cut from the hoop 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 no more than 0,1L 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 hoop 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 hoop 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 hoop 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.

Table B.1 — Values for longitudinal test piece width, b , in relation to mean wall thickness, e_m

Dimensions in millimetres

Mean composite thickness e_m	Width b
$e_m \leq 15$	$15,0 \pm 1$
$15 < e_m \leq 25$	$25,0 \pm 1$
$25 < e_m \leq 35$	$35,0 \pm 1$
$e_m > 35$	$50,0 \pm 1$

B.3.4 Length

Test pieces to be tested with nominal span, L , less than $16e_m$ (see B.4.2 below) shall be cut to a length of not less than $L \pm 4e_m$.

B.4 Procedure

NOTE The following requirements modify or supplement those of ISO 178:2001, 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, using a measuring device with accuracy of within $\pm 0,01\text{mm}$. 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 and/or excess neat resin layers.

Any excess neat resin on the back of the test piece (corresponding to outside of liner pipe), especially if forming a layer of irregular thickness, may be partially or wholly ground off prior to testing, provided that no fibres of the carrier material and/or reinforcement are thereby removed.

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

If the mean value of composite thickness, e_m , of any individual test piece deviates by more than 10 % from the mean, e_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

If possible, the nominal distance, L , between supports shall be set to $(16 \pm 1)e_m$. Exceptions additional to those described in 8.3 of ISO 178:2001 are as follows.

- If curved test pieces are used, the rise, V , of the centre of the unloaded test piece above its points of contact with the supports shall not exceed $0,07L_1$, where L_1 is the distance between the points of contact (see Figure B.1). If necessary to achieve this, the nominal span ratio, L/e_m , may be reduced below 16 but to not less than 10.

NOTE 1 In the case of hoop test pieces cut from circular pipe samples of nominal outside diameter, d_n , the limit of curvature expressed as a maximum rise, V , of $0,07L_1$, corresponds to a maximum nominal span to diameter ratio, L/d_n , of approximately 0,25.

NOTE 2 The value of apparent flexural modulus derived from a curved test piece is generally lower than that obtained from flat test pieces of the same material, due to geometric effects and slippage on the supports. At the specified limit of curvature, for a nominal span/thickness ratio, $L/e_m = 16$, the maximum discrepancy is of the order of 10 % to 15 %.

NOTE 3 Samples taken from liners of diameter less than about 200 mm to 300 mm (dependent on wall thickness) do not generally comply with the geometrical restrictions on 3-point flexural testing in the hoop direction. Such samples should either be tested as complete rings or, for materials with isotropic properties conforming to 8.8 a), as flexural test pieces cut in the longitudinal direction.

b) In the case of relatively thick-walled liners from which it is difficult or impossible to acquire samples of length at least $20L$, the nominal span/thickness ratio L/e_m may again be reduced below 16 but to not less than 10.

NOTE 4 Using a span/thickness ratio of less than 16 can lead to a slight underestimate of flexural modulus and strength.

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 , defined by Figure B.1, shall be derived from Equation B.1:

$$L_2 = \frac{L}{1 - \left(\frac{r + h_m / 2}{R_2} \right)} \tag{B.1}$$

where

r is the radius of the supports;

h_m is the mean total thickness of the test piece (measured in accordance with Figure B.3);

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

In the case of hoop test pieces cut from circular liner pipe of known outside diameter, d_n , R_2 may simply be assigned the value:

$$R_2 = \frac{d_n - h_m}{2} \tag{B.2}$$

In all other cases, R_2 shall be determined either

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

$$R_2 = \frac{V}{2} + \frac{L_1^2}{8V} + \frac{h_m}{2} \tag{B.3}$$

where the values of dimensions, V and L_1 , 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 $R_1 (= R_2 - h_m / 2)$ of the circular arc which best fits that profile.

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 $\pm 0,5$ 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 178:2001, 9.1 and 9.3.

B.5.1 Span and thickness for calculation

If curved samples are used, the span for calculation of flexural properties shall be L_2 , as defined by Equation (B.1), rather than the distance, L , between the centres of the supports. The thickness for calculation shall be the mean composite thickness, e_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 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 flexural modulus from uncorrected strain data shall also be used to derive the true strain datum.

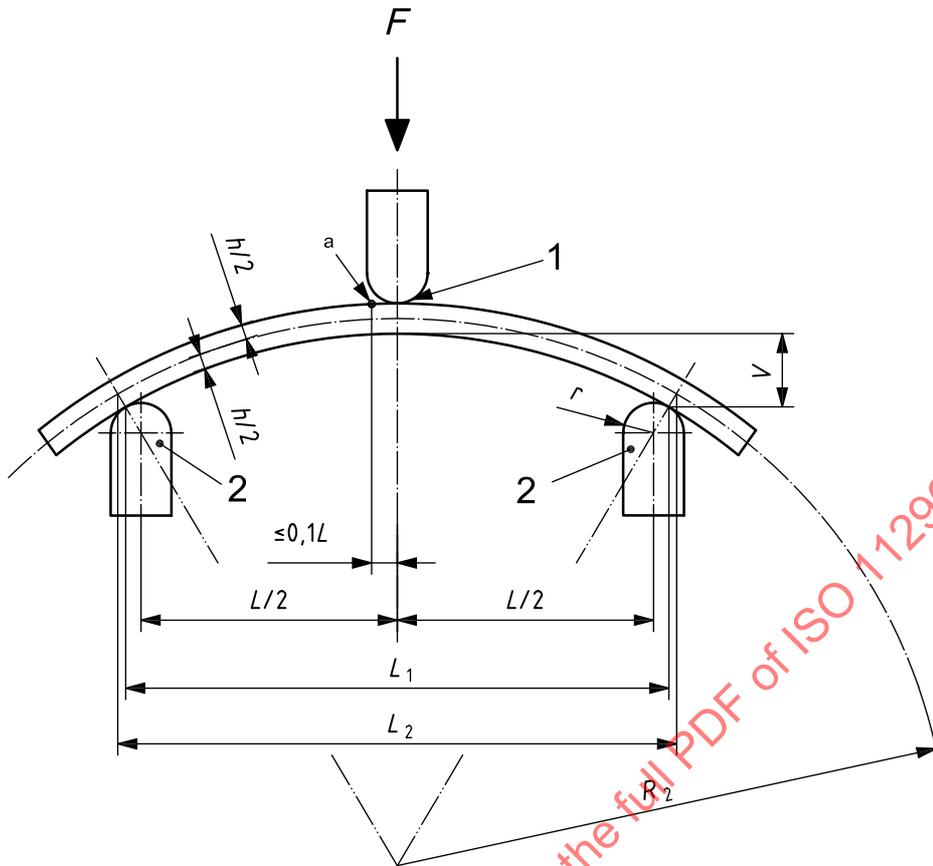
B.5.3 Derivation of flexural modulus

When using uncorrected strain data, the short-term flexural modulus, E_0 , shall be determined by the procedure in ISO 178:2001, 9.3, using 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 $(\varepsilon_{fi})_{\text{corrected}} = (\varepsilon_{fi})_{\text{uncorrected}} - \varepsilon_{f0}$. 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.6 Test report

The test report shall include, in addition to the information specified in ISO 178:2001, 11 c) and h):

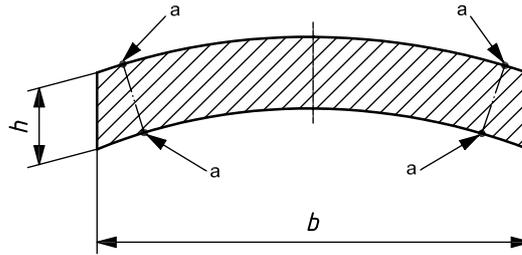
- a) for pipe samples, the orientation of each test piece (i.e. hoop or longitudinal);
- b) the mean composite thickness and the maximum percentage deviation from the mean in the middle third of the test piece;
- c) in the case of curved hoop test pieces: the mean total thickness, h_m ; true span, L_2 ; the value and method of determination of radius R_2 ; and, where directly measured, the dimensions L_1 and V .



Key

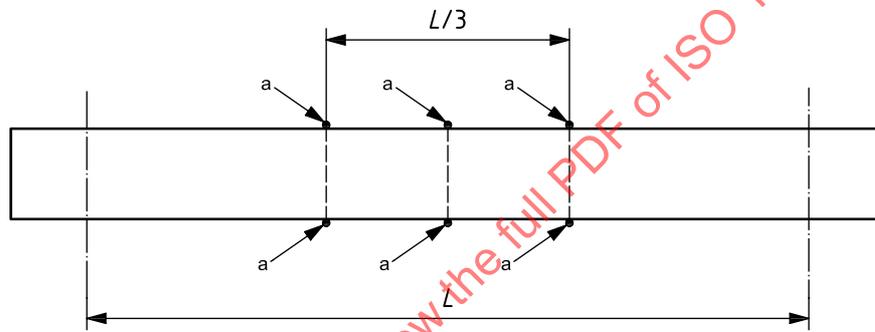
- 1 striking edge
- 2 support
- F applied force
- h total thickness of test piece
- L distance between supports
- L_1 distance between points of contact of the unloaded test piece with the supports
- L_2 true span of curved test piece
- r radius of support
- R_2 radius of curvature of test piece at mid-thickness
- V rise of the centre of the unloaded test piece above its points of contact with the supports
- a High point of the test piece.

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

**Key**

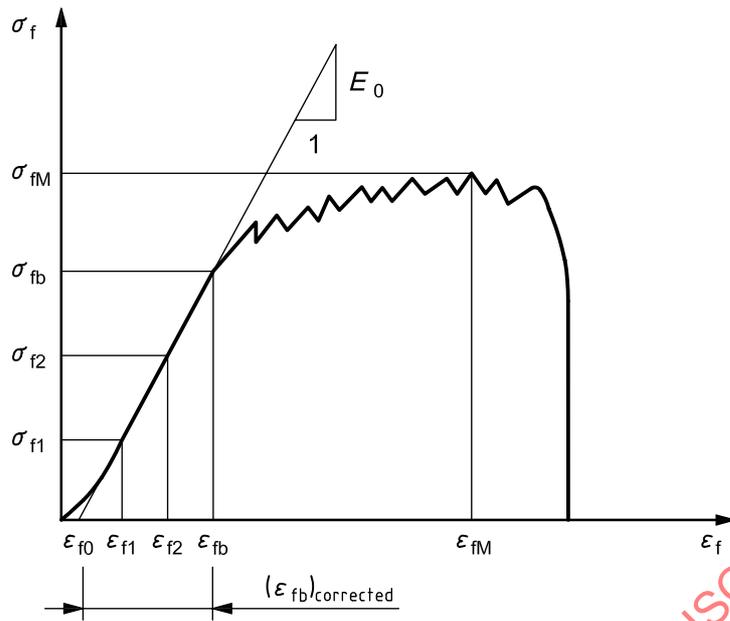
- h thickness of test piece
- b width of test piece
- a Measuring point.

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

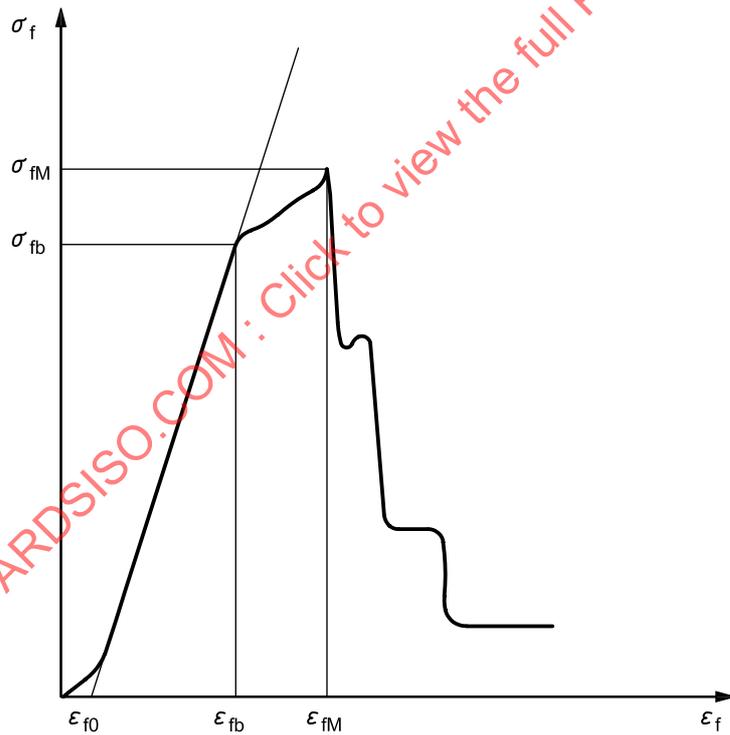


- a Measuring point.

Figure B.3 — Plan view of test piece (hoop 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 — Test method for the determination of long-term flexural modulus under 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 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 immersed in water and subjected to three-point bending under constant load, under conditions of controlled temperature and relative humidity. 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, 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;
- 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 sample, oriented in either the hoop or longitudinal direction according to the criteria of 8.8 and with dimensions and tolerances as specified in B.3.