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Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the apparent initial circumferential tensile strength

Systèmes de canalisations en matières plastiques — Tubes en plastiques thermodurcissables renforcés de verre (PRV) — Détermination de la résistance en traction circonférencielle initiale apparente

Reference number
ISO 8521:1998(E)

Foreword

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International Standard ISO 8521 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids,* Subcommittee SC 6, *Reinforced plastics pipes and fittings for all applications,* in collaboration with CEN/TC 155, *Plastics piping systems and ducting systems.*

This standard is one of a series of standards on test methods which support standards for plastics piping systems and ducting systems.

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Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the apparent initial circumferential tensile strength

1 Scope

This standard specifies six test methods for the determination of the apparent initial tensile strength in the circumferential direction per unit length of glass-reinforced thermosetting plastics (GRP) pipes.

The burst test (method A) is suitable for all types and sizes of pipes. It is the reference method.

The split disc test (method B) may not be suitable for pipes with helically wound reinforcing layers.

The strip test (method C) and the modified strip test (method D) are suitable for pipes with a nominal size of DN 500 and greater.

The restrained strip test (method E) is suitable for all types of pipes with a nominal size greater than DN 500.

The notched plate test (method F) is primarily intended for use for helically wound pipes of nominal size greater than DN 500 with a winding angle other than approximately 90°.

Results from one method are not necessarily equal to the results derived from any of the alternative methods.

2 Definitions

For the purposes of this standard, the following definitions apply:

2.1 apparent initial circumferential strength (σ_{cA}^*, σ_{cB}^*, σ_{cC}^*, σ_{cD}^*, σ_{cE}^*, σ_{cF}^*): Ultimate circumferential tensile force per unit length in the circumferential direction (the upper-case subscripts denote the method of test used).

It is expressed in newtons per millimetre of circumference.

2.2 burst pressure (p_{ult}): The internal pressure at bursting.

It is expressed in bars[1)] (or megapascals).

2.3 bursting: Failure by rupture of the pipe wall.

2.4 ultimate tensile force (F_{ult}): The tensile force at failure.

It is expressed in newtons.

2.5 width (b): The width of the test piece in the notched area.

It is expressed in millimetres.

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

2.6 winding angle (θ): The angle between the direction of the reinforcement and the longitudinal axis of the pipe.

It is expressed in degrees.

3 Principle

NOTE It is assumed that the following test parameters are set by the standard making reference to this standard:

a) for method A the length between the end sealing devices (see 5.1);

b) for methods B, C, D and E the width of the test piece (see 5.2, 5.3, 5.4 and 5.5);

c) for methods C and E the total width of the test piece (see 5.3 and 5.5);

d) for method F the dimensions of the plate to be tested (see 5.6);

e) the number of test pieces (5.7);

f) the requirements for conditioning (see clause 6);

g) the test temperature (see clause 7).

3.1 Method A

The apparent initial circumferential strength, σ_{cA}^*, is determined by a burst test.

Cut lengths of pipe are subjected to an increasing internal pressure which, within a specified time, causes bursting (see 2.3).

The test conditions are such that a mainly uniaxial circumferential stress is obtained.

3.2 Method B

The apparent initial circumferential strength, σ_{cB}^*, is determined by a split disc test.

Rings cut from the pipe are subjected to an increasing tensile force by means of a split disc within the ring until rupture occurs, within a specified time.

3.3 Methods C, D and E

The apparent initial circumferential strength, σ_{cC}^*, σ_{cD}^*, σ_{cE}^*, is determined by a strip test.

Strips cut from the pipe wall in the circumferential direction are subjected to an increasing tensile force until rupture occurs within a specified time.

3.4 Method F

The apparent initial circumferential strength, σ_{cF}^*, is determined by a notched plate test.

Plates cut from the pipe wall are subjected to an increasing tensile force until rupture occurs within a specified time.

4 Apparatus

4.1 For method A

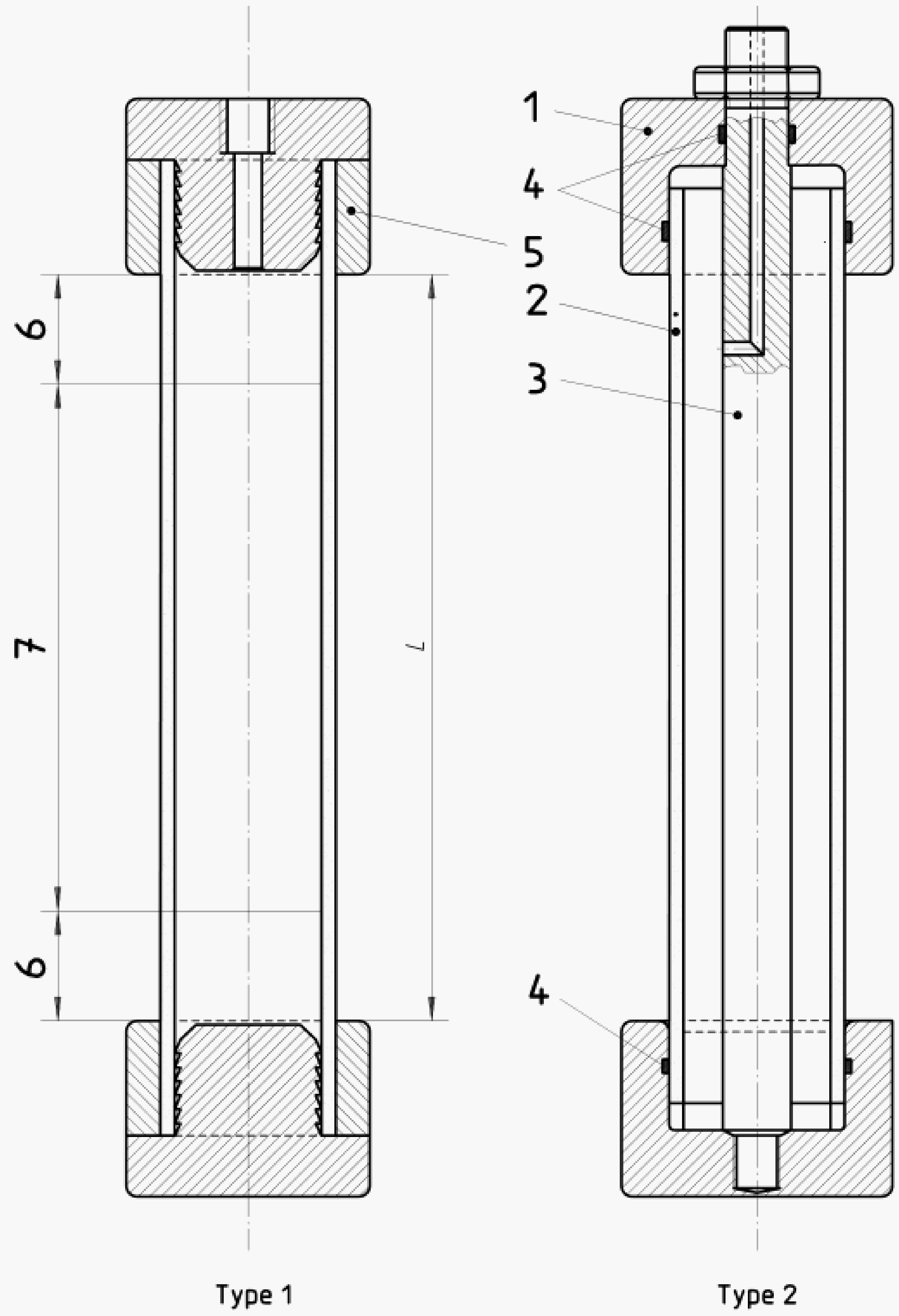
4.1.1 Hydrostatic pressurizing system, for pipes of up to DN 500, capable of causing failure of the test piece between 1 min and 3 min after commencing the pressurization. For nominal sizes greater than DN 500 the duration of the test may have to be increased.

The pressurizing system shall prevent air entering the test piece during pressurization to failure.

4.1.2 Pressure measurement device, capable of measuring with an accuracy of ± 2,0 % of the applied pressure.

4.1.3 End sealing devices for the test pieces, such that a mainly uniaxial state of stress in the circumferential direction will be induced (i.e. type 1 or type 2 in figure 1).

4.1.4 Test piece support, to minimize deformation due to the weight of the test piece and its contents.



Key

1 End cap
2 Test piece
3 Tie bar carrying end thrust
4 Elastomeric seal
5 End cap
6 See 8.1.3 for this dimension
7 Valid failure zone
L Length of test piece

Type 1: Testing with end thrust (external seals)

Type 2: Testing without end thrust (internal seals)

Figure 1 — Typical arrangement for pressure testing of pipes

4.1.5 Flexible membrane (if used as a barrier system to prevent weeping), which does not reduce the stress in the pipe wall by more than 1 %.

The flexible membrane may be of a different material from the pipe, e.g. elastomeric or thermoplastic sheet or a flexible coating.

4.2 For method B

4.2.1 Test machine, of the type capable of producing a progressive separation of the split disc, incorporating the following components:

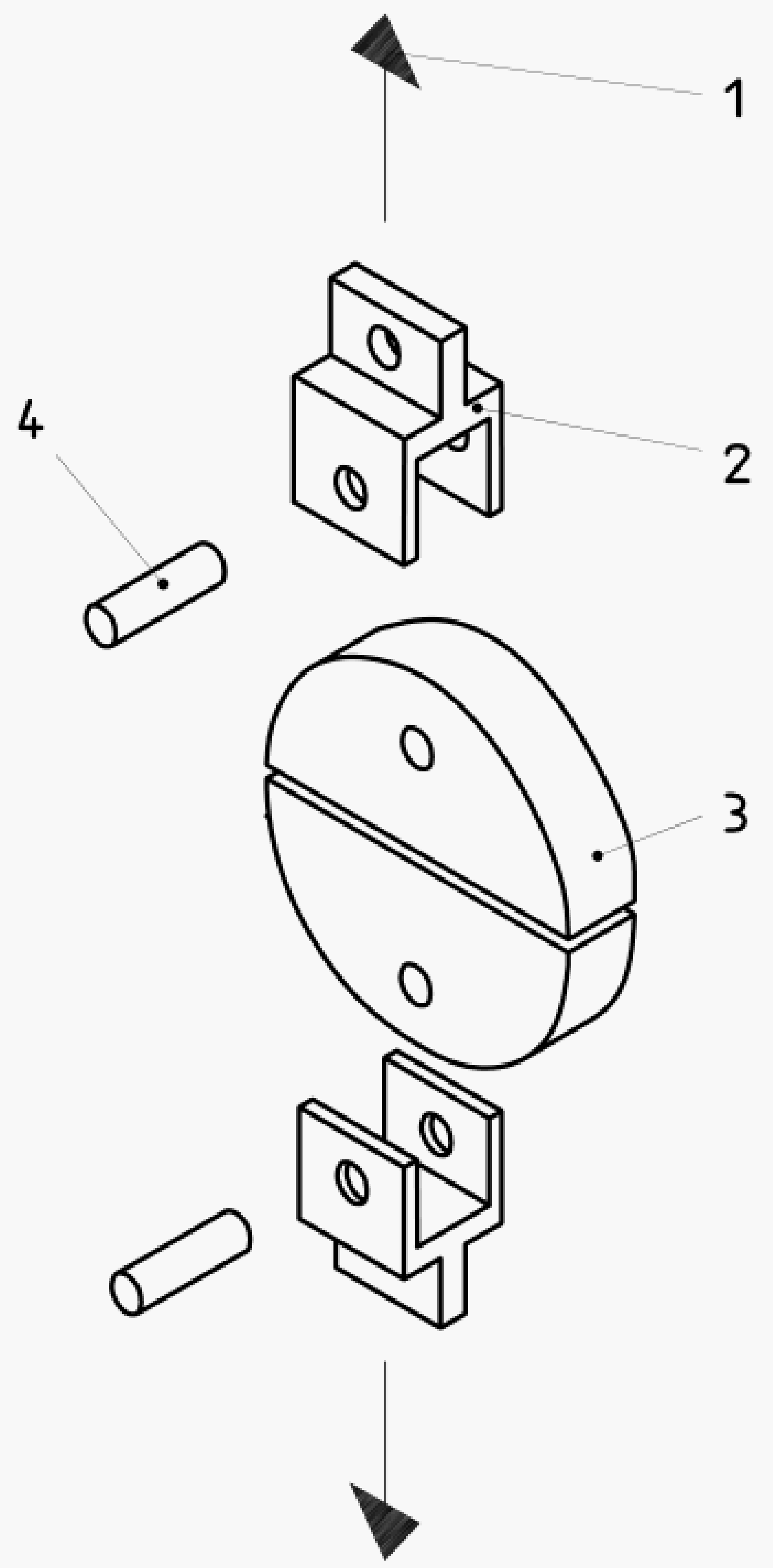
a) a fixed or virtually fixed part;

b) a moveable part;

c) a drive mechanism capable of imparting a constant speed to the moving part so that rupture can be reached between 1 min and 3 min after initial loading;

d) a load indicator capable of measuring the force applied. This shall be virtually free from inertia at the specified rate of testing and shall indicate the force to an accuracy of within 1 % of the measured value.

4.2.2 Rigid split discs, as shown in figure 2, capable of making even contact with the internal diameter of the test piece. The diameter of the two segments of the split disc shall be not less than 98 % of the internal diameter of the pipe with which they are intended to be used.



Key

1 Direction of loading
2 Toggle
3 Saddle
4 Shear pins

Figure 2 — Typical arrangement for the split disc

4.2.3 Dimension measurement devices, capable of measuring the necessary dimensions of the test piece (e.g. length, wall thickness) to an accuracy of half the accuracy required in clause 8 measurements, e.g. measuring accuracy ± 0,1 mm requires a device accuracy of ± 0,05 mm.

4.3 For method C

4.3.1 Test machine, of the type with constant separating speed, incorporating the following components:

a) A fixed, or virtually fixed, part with a grip to hold one end of a test piece.

b) A moveable part, incorporating a second grip to hold the other end of the test piece. The grips holding the ends of the test piece shall do so as far as possible without slipping and/or crushing.

NOTE Grips which tighten automatically may be used.

The fixed and moving parts and their associated grips shall enable the test piece to be aligned when a force is applied so that the axis of the test piece is coincident with that of the force.

c) A drive mechanism capable of imparting a constant speed to the moving part, so that failure can be reached between 1 min and 3 min after initial loading.

d) A load indicator capable of measuring the force applied. The mechanism shall be virtually free from inertia lag at the specified rate of testing and shall indicate the force with an accuracy of within 1 % of the measured value.

4.3.2 Dimension measuring device(s), for measuring the widths, b and b_{tot}, and the free length, l, of the test piece (see figure 5) to an accuracy of ± 0,1 mm.

4.4 For method D

4.4.1 Test machine, conforming to 4.3.1.

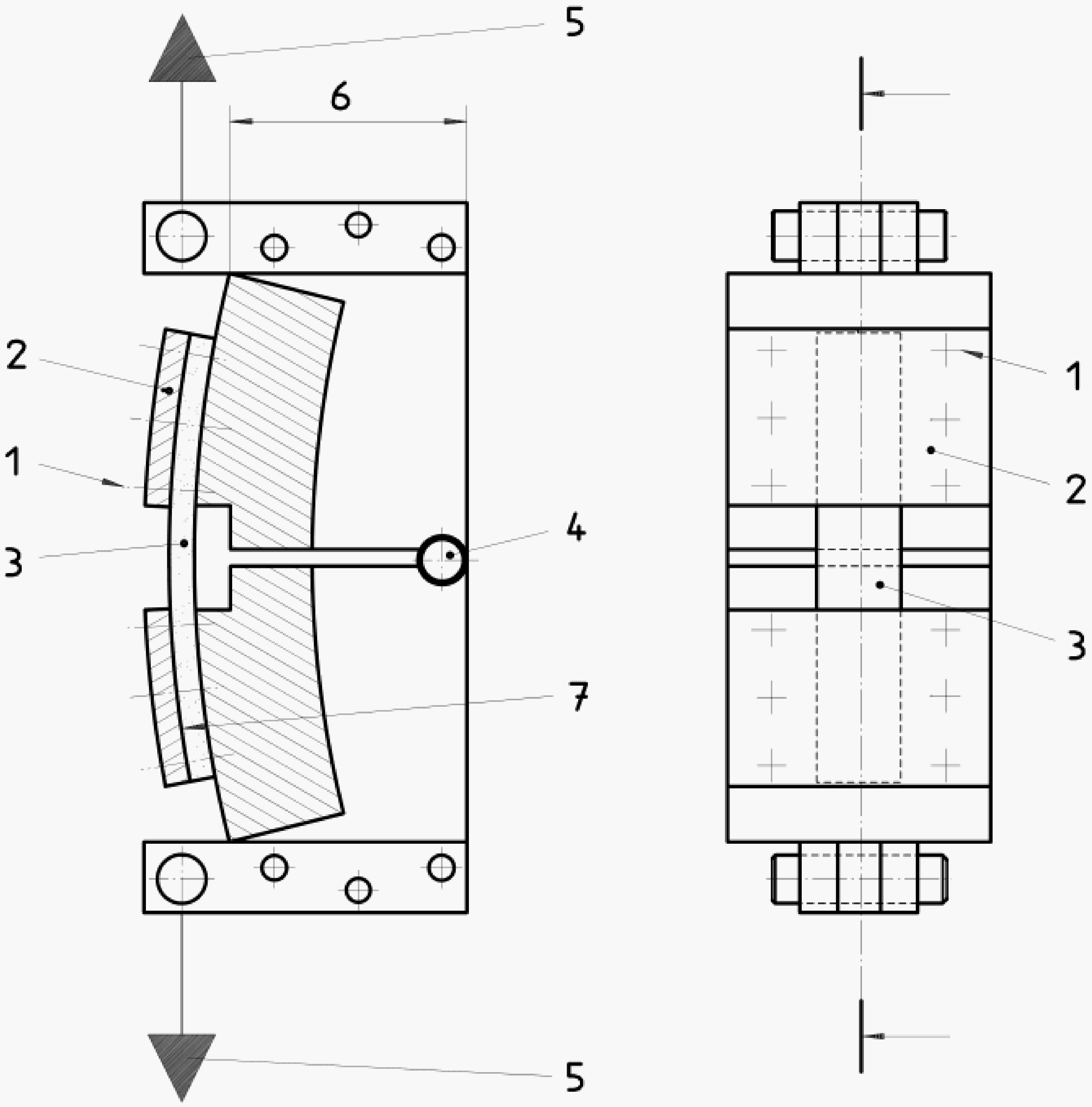
4.4.2 Dimension measuring device(s), capable of measuring the width, b and the thickness, e, of the test piece (see figure 6) to an accuracy of ± 0,1 mm.

4.5 For method E

4.5.1 Test machine, conforming to 4.3.1.

4.5.2 Dimension measuring device(s), capable of measuring the widths, b and b_{tot}, and the length, l, of the test piece (see figure 7) to an accuracy of ± 0,1 mm.

4.5.3 Restraining fixture, that prevents the test piece bending. The radius of curvature of the support plate shall be half the nominal size, DN, expressed in millimetres, ± 5 %. An example of such a fixture is shown in figure 3.



Key

1 Bolt
2 Clamping plate
3 Test piece
4 Pivot
5 Direction of loading
6 Adjustable distance
7 Radius = 0,5 × external diameter

Figure 3 — Typical arrangement for restrained strip test with a split support

4.6 For method F

4.6.1 Test machine, conforming to 4.3.1.

4.6.2 Load indicator, capable of indicating the force applied to the test piece to an accuracy of ± 1 % of the indicated value.

4.6.3 Means of measuring the width, b, (see figure 8) of the neck of the test piece to an accuracy of ± 0,1 mm **and the winding angle**, θ, to an accuracy of ± 1°.

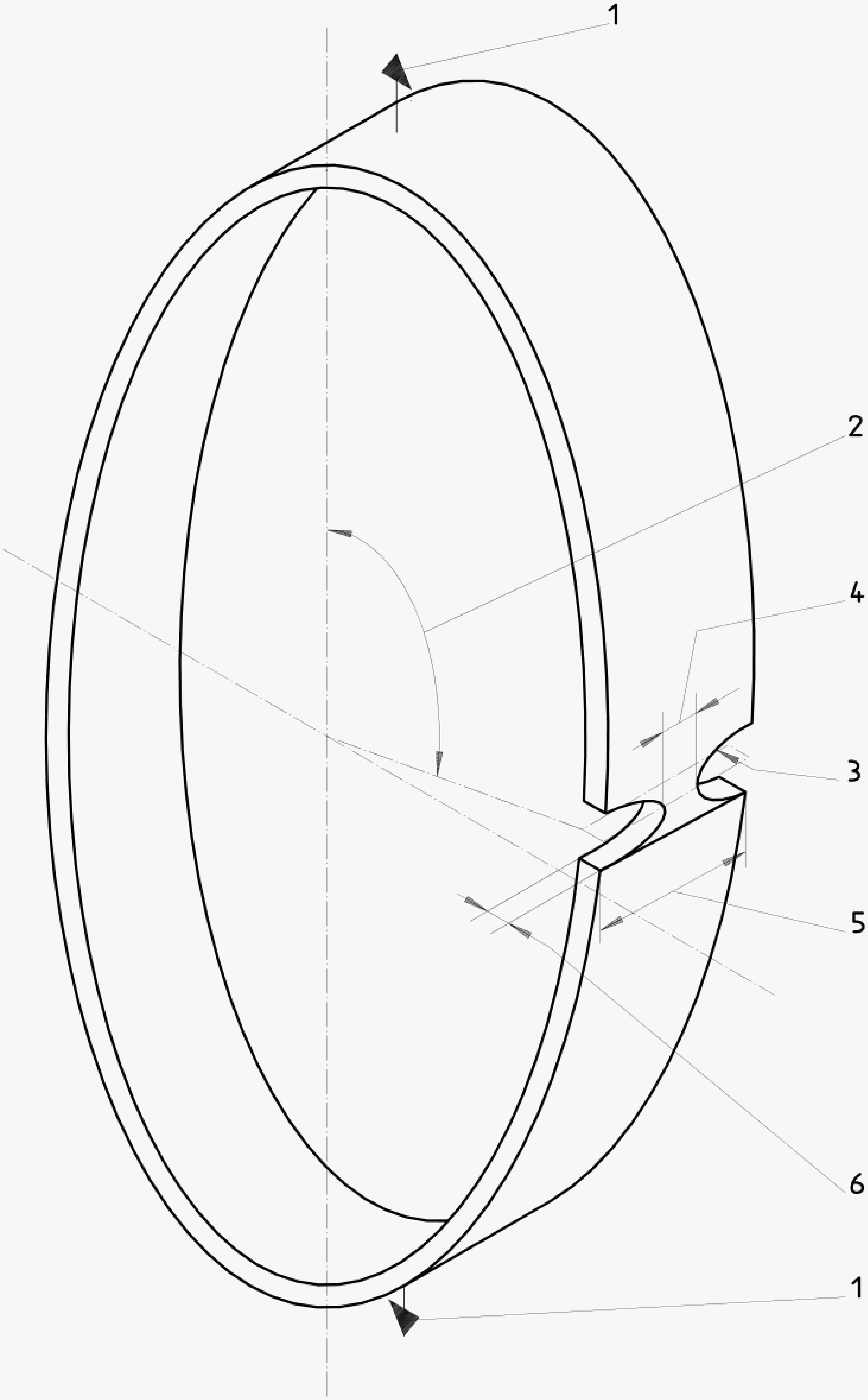
5 Test pieces

5.1 For method A

The test piece shall be a cut length of pipe whose length between the end sealing devices shall be as specified in the referring standard.

5.2 For method B

The test piece shall be a ring cut from a pipe and its dimensions shall conform to figure 4.



Key

1 Direction of loading
2 Angle approximately 80°
3 Radius 10 mm min.
4 Width of test section (15 mm min.)
5 Width of test piece, b (25 mm min.)
6 Wall thickness, e

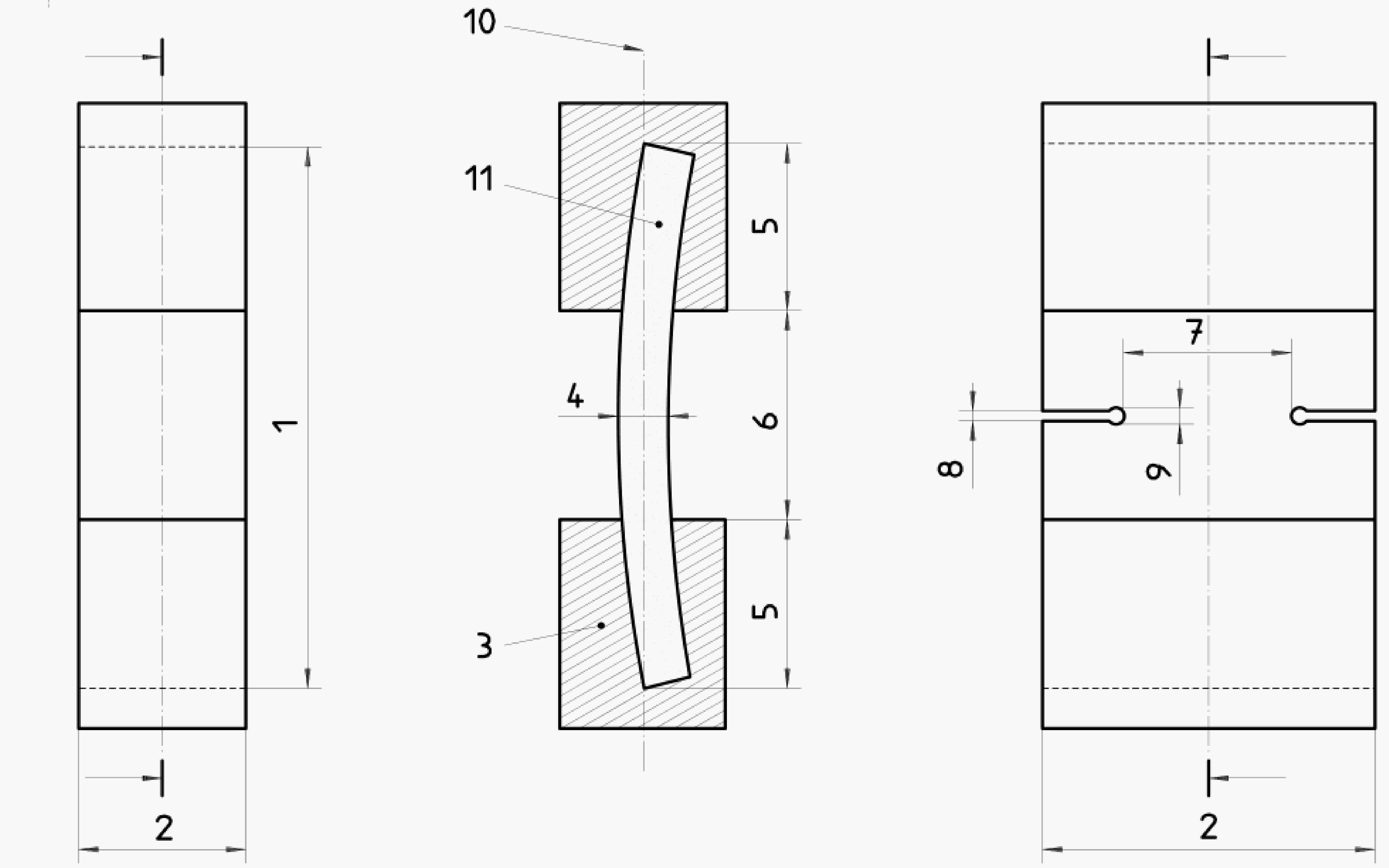
Figure 4 — Test piece for split disc test

The width of the test piece shall not exceed the width of the split disc.

The ends of the ring shall be smooth and perpendicular to the axis of the pipe.

5.3 For method C

The test pieces (see figure 5) shall be cut out of the pipe in the circumferential direction.



a) Case 1: No helically wound layers

b) Case 2: Helically wound layers

Key

1 l + 100 mm
2 b_{tot}
3 Cast resin end
4 Wall thickness, e
5 50 mm
6 l (between 4e and 5e)
7 b (25 mm min.)
8 Free slot width (between 1 mm and 5 mm)
9 5 mm
10 Centreline
11 Test piece

Figure 5 — Test piece for strip test

The test piece conforming to case 1 (see figure 5) shall be used when helically wound reinforcing layers (i.e. $\theta > 70°$) are not present. The test piece conforming to case 2 (see figure 5) shall be used when helically wound reinforcing layers are present.

The ends shall be smooth and perpendicular to the axis of the pipe.

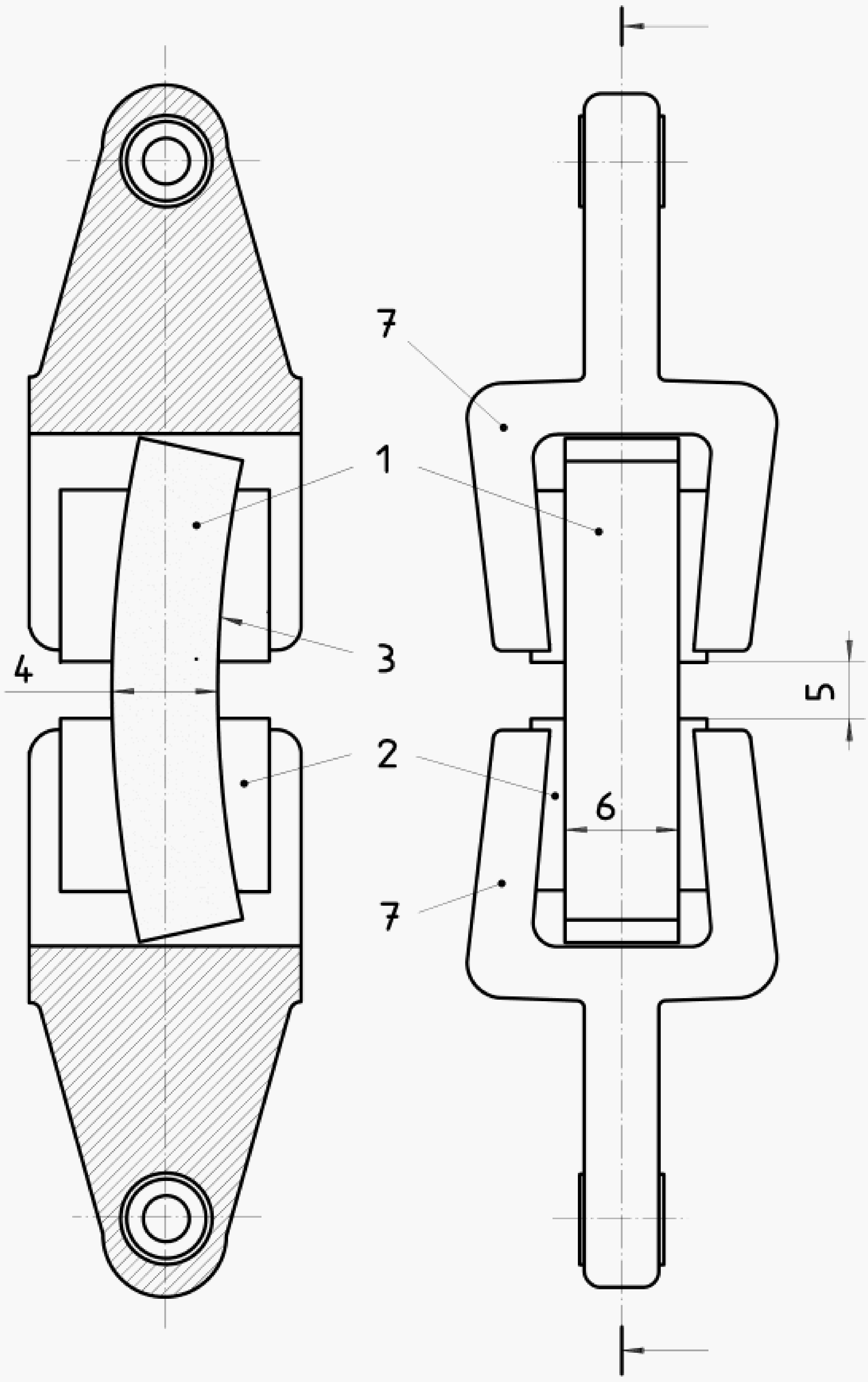
For case 1 the total width, b_{tot}, shall be as specified in the referring standard but at least (25 ± 0,5) mm.

For case 2 the total width, b_{tot}, shall be as specified in the referring standard but at least 2 × b ($b \geqslant 25$ mm) to prevent shear failure. Failures not occurring in the notched area shall not be taken into account.

The ends of the strip shall be encased in thermosetting resin as shown in figure 5.

5.4 For method D

The test piece (see figure 6) shall be cut from the pipe in the circumferential direction.



Key

1 Test piece
2 Tapered clamp
3 Inside diameter
4 Pipe wall thickness, e
5 Distance between grips (between 10 mm and 20 mm)
6 Width of test piece, b (10 mm min.)
7 Grip

Figure 6 — Typical test arrangement for modified strip test

The faces of the test piece in contact with the clamp shall be smooth and perpendidular to the axis of the pipe.

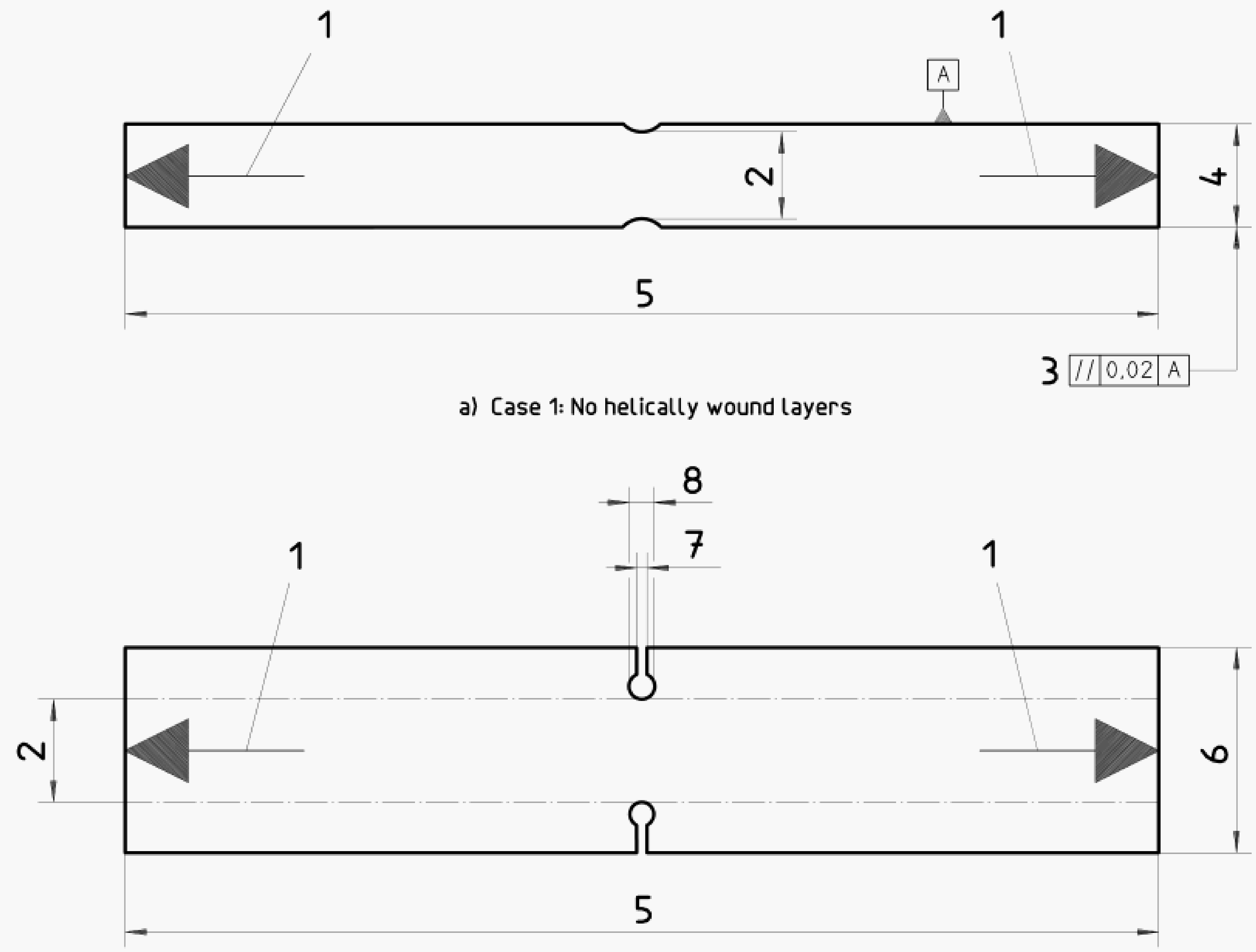
The width, b, shall be as specified in the referring standard but not less than 10 mm.

In order to prevent shear failure, the distance between the grips, l_g, shall be (15 ± 5) mm.

The total length of the test piece shall be adjusted to suit the grip arrangement.

5.5 For method E

The test piece shall be cut out of the pipe in the circumferential direction and shaped to the dimensions shown in figure 7. Alternatively when it is required only to determine conformity to a minimum strength requirement, parallel-sided strips 25 mm wide may be used. If, when using parallel-sided strips, the test piece fails before the minimum force is applied the test shall be repeated using a test piece conforming to figure 7.



a) Case 1: No helically wound layers

b) Case 2: Helically wound layers

Key

1 Circumferential direction
2 Test width, b (between 24 mm and 26 mm)
3 Sides parallel to within 2 %
4 Total width, b_{tot}
5 Length of test piece, l (between 250 mm and 350 mm)
6 Total width, b_{tot} (minimum of 48 mm to prevent shear failures)
7 Free slot width (between 1 mm and 5 mm)
8 5 mm min.

Figure 7 — Test piece for restrained strip test

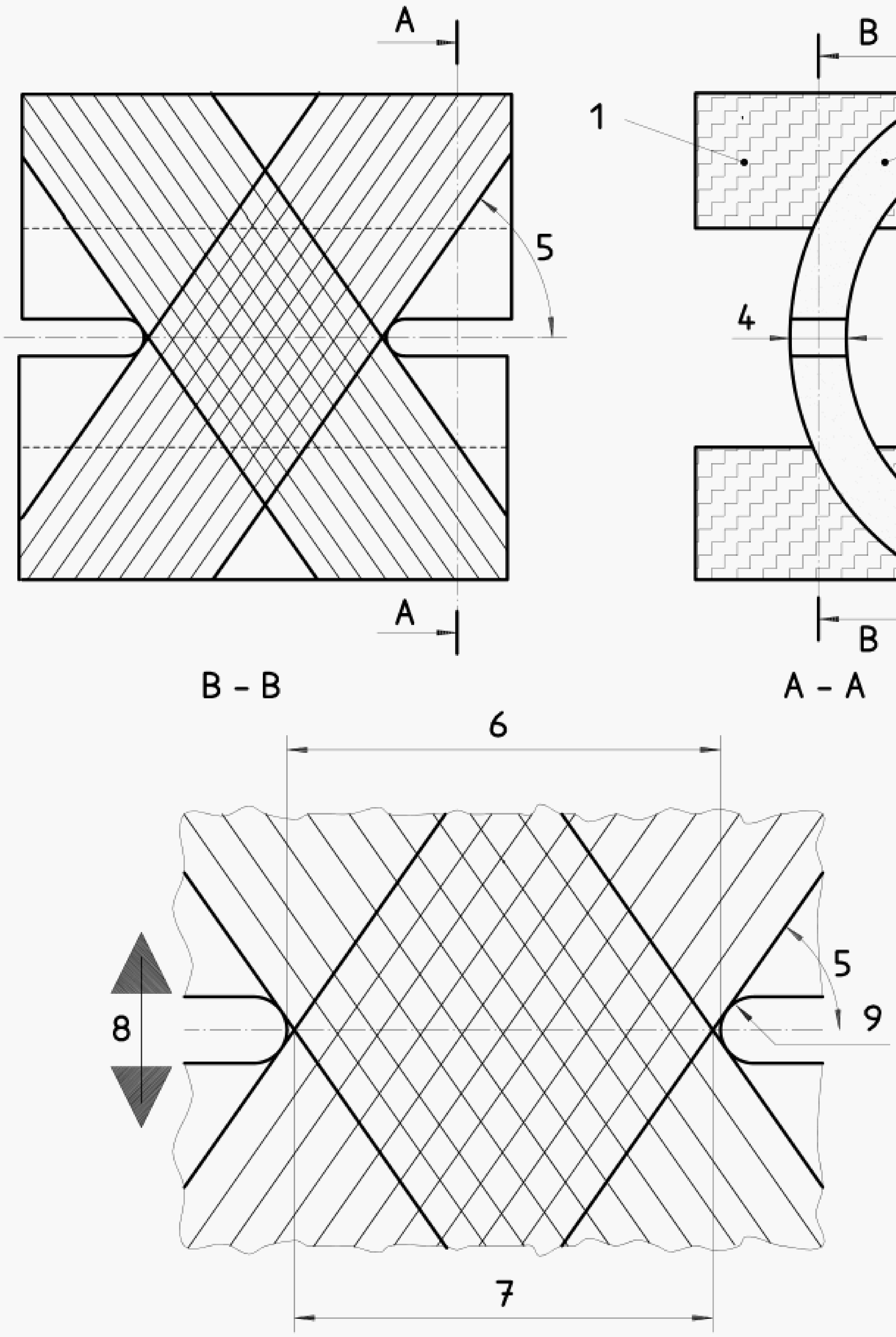
The test piece conforming to case 1 (see figure 7) shall be used when no helically wound reinforcing layers with $\theta > 70°$ are present. The test piece conforming to case 2 (see figure 7) shall be used when helically wound reinforcing layers are present.

For case 2 the total width, b_{tot}, shall be as specified in the referring standard but at least $2 \times b$ to prevent shear failure.

5.6 For method F

The test piece shall be cut approximately square from the pipe.

The dimensions of the test piece shall be as specified in the referring standard but sufficiently large to ensure that failure occurs across the neck of the test piece (see figure 8).

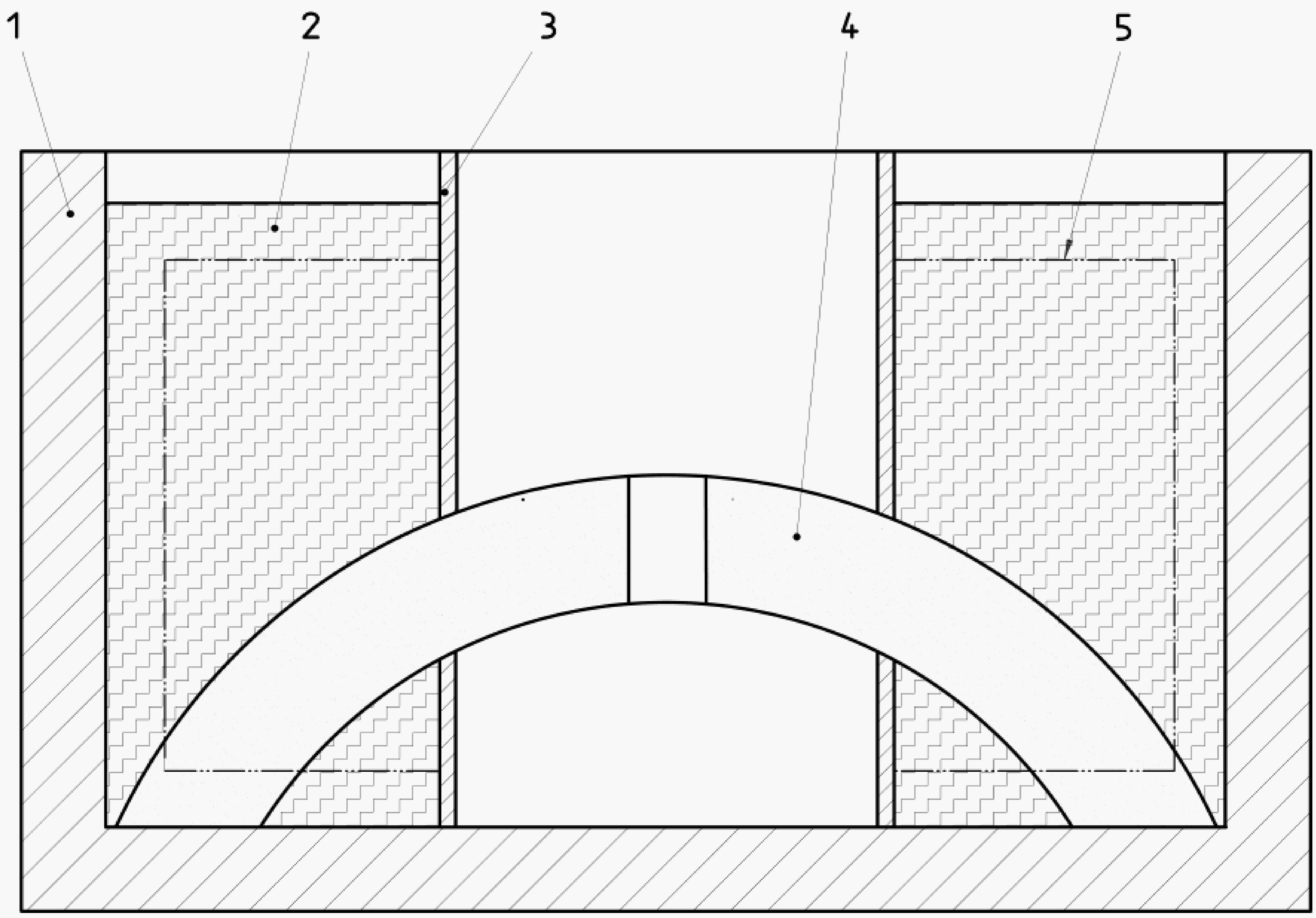


Key

1 Thermosetting resin
2 Pipe section test piece
3 Distance between grips (4e min.)
4 Pipe wall thickness, e
5 Winding angle of glass fibres
6 Width of neck, b (between 4e and 5e)
7 Stressed width, $b + 2r[1 - 1/\sin(\text{winding angle})]$
8 Circumferential direction
9 Radius within neck of test piece, r

Figure 8 — Plate test piece

The test piece ends shall be built up with thermosetting resin with or without reinforcement. When cured, machine the built-up ends flat and parallel, and ensure that the centroid of the gauge length cross-section (see figures 8 and 9) will lie on the loading centreline of the test machine when gripped.



Key

1 Outer mould
2 Thermosetting resin
3 Inner void former
4 Pipe section test piece
5 Profile of ends after trimming

Figure 9 — Resin application to the plate test piece

Any flash shall be removed and the test piece shall be machined to the following dimensions (see figure 8):

— distance between the grips, l_g:

$l_g \geqslant 4e$;

— radius within the neck of the test piece, r:

$0{,}2e \leqslant r \leqslant 0{,}5e$;

— width, b, of the neck:

$4e \leqslant b \leqslant 5e$.

5.7 Number of test pieces

The number of test pieces shall be as specified in the referring standard.

6 Conditioning

Unless otherwise specified by the referring standard, store test pieces at the test temperature (see clause 7) for at least 0,5 h prior to testing.

7 Test temperature

The test shall be conducted at the temperature specified in the referring standard.

8 Procedure

8.1 For method A

8.1.1 Determine the internal diameter, d_i, to an accuracy of ± 1 %.

8.1.2 Attach the end sealing devices to the test piece and fill the assembly with water. Attach the assembly to the pressurizing system, taking care to avoid entrapment of air.

8.1.3 Pressurize at a rate such that failure occurs in the valid failure zone (see figure 1) between 1 min and 3 min after starting to apply pressure.

The dimension labelled 6 in figure 1 is obtained, in millimetres, from the following equation:

$$\text{Dimension in millimetres} = 3{,}3 \times (\text{DN} \times e)^{0{,}5}$$

where

DN is the nominal size of the pipe, in millimetres;

e is the wall thickness of the pipe, in millimetres.

Record the maximum pressure reached, in bars, and the time to failure.

8.2 For method B

8.2.1 Measure to an accuracy of ± 0,1 mm the width, b, of the test piece as the average of two measurements one of which shall be taken at the inside surface of the ring in the notched area and one at the outside surface of the ring in the notched area.

8.2.2 Mount the test piece on the outside periphery of the split disc with the expected failure zone located as shown in figure 4.

8.2.3 Apply a constant separating speed to the split disc such that failure occurs between 1 min and 3 min. Record the maximum force and the time to failure. Failure shall occur in the notched area.

8.3 For method C

8.3.1 Measure the width, b, of the test piece to an accuracy of ± 0,1 mm.

8.3.2 Fix the test piece in the grips so that the load will be applied through the centreline of the test piece (see figure 5).

8.3.3 Apply a constant separating speed to the grips so that failure occurs between 1 min and 3 min. Record the maximum force and the time to failure. When using test pieces in accordance with case 2, failures not occurring in the notched area shall be discarded.

8.4 For method D

8.4.1 Measure the width, b, and the wall thickness, e, of the test piece to an accuracy of ± 0,1 mm.

8.4.2 Fix the test piece in the grips (see figure 6) so that the force is applied through the centreline of the test piece. When fixing the test piece in the grips, take care to ensure that the midpoint of the test piece is located at approximately the midpoint of l_g.

8.4.3 Apply a constant separating speed to the grips so that failure occurs between 1 min and 3 min. Record the maximum force and the time to failure.

8.5 For method E

8.5.1 Measure the width, b, of the test piece to an accuracy of ± 0,1 mm.

8.5.2 Fix the test piece in the grips and align the restraining fixture so that no bending occurs in the test piece. Locate the test piece so that its centreline is coincident with the loading axis of the machine.

8.5.3 Apply a constant separating speed to the grips so that failure occurs between 1 min and 3 min. Record the maximum force and the time to failure. When using test pieces in accordance with case 2, failures not occurring in the notched area shall be discarded.

8.6 For method F

8.6.1 Measure the width, b, of the test piece to an accuracy of ± 0,1 mm and the winding angle, θ, to an accuracy of ± 1°. Determine by measurement and/or calculation the radius, r.

8.6.2 Locate the test piece so that its centreline is coincident with the loading axis of the machine.

8.6.3 Apply a constant separating speed to the grips so that failure occurs between 1 min and 3 min. Record the maximum force and the time to failure.

Discard the result of any test piece that breaks other than across the neck.

9 Calculation

NOTE The subscript "x" used in the following is the number of the test piece.

9.1 For method A

For each test piece calculate the apparent initial circumferential strength, $\sigma_{cA,x}^*$, in newtons per millimetre of circumference, using the following equation:

$$\sigma_{cA,x}^* = 0,05 \times p_{ult} \times d_i$$

where

p_{ult} is the internal pressure at burst, in bars;

d_i is the internal diameter of the pipe, in millimetres.

Calculate the average apparent initial circumferential strength, σ_{cA}^*, of the test pieces and, if applicable, the standard deviation.

9.2 For method B

For each test piece calculate the apparent initial circumferential strength, $\sigma_{cB,x}^*$, in newtons per millimetre of circumference, using the following equation:

$$\sigma_{cB,x}{}^* = \frac{F_{ult}}{2 \times b}$$

where

F_{ult} is the ultimate force, in newtons;

b is the width of the test piece in the notched area (see 8.2.1), in millimetres (see figure 4).

Calculate the average apparent initial circumferential strength, σ_{cB}^*, of the test pieces and, if applicable, the standard deviation.

9.3 For method C, D and E

For each test piece calculate the apparent initial circumferential strength, $\sigma_{cC,x}^*$, $\sigma_{cD,x}^*$, $\sigma_{cE,x}^*$, in newtons per millimetre of circumference, using one of the following equations:

$$\sigma_{cC,x}{}^* = \frac{F_{ult}}{b}$$

or

$$\sigma_{cD,x}{}^* = \frac{F_{ult}}{b}$$

or

$$\sigma_{cE,x}{}^* = \frac{F_{ult}}{b}$$

where

F_{ult} is the ultimate force, in newtons;

b is the width of the test piece, in millimetres.

Calculate the average apparent initial circumferential strength, σ_{cC}^*, σ_{cD}^*, σ_{cE}^*, of the test pieces and, if applicable, the standard deviation.

9.4 For method F

For each test piece calculate the apparent initial circumferential strength, $\sigma_{cF,x}^*$, in newtons per millimetre of circumference, using the following equation:

$$\sigma_{cF,x}{}^* = \frac{F_{ult}}{b + 2r(1 - 1/\sin\theta)}$$

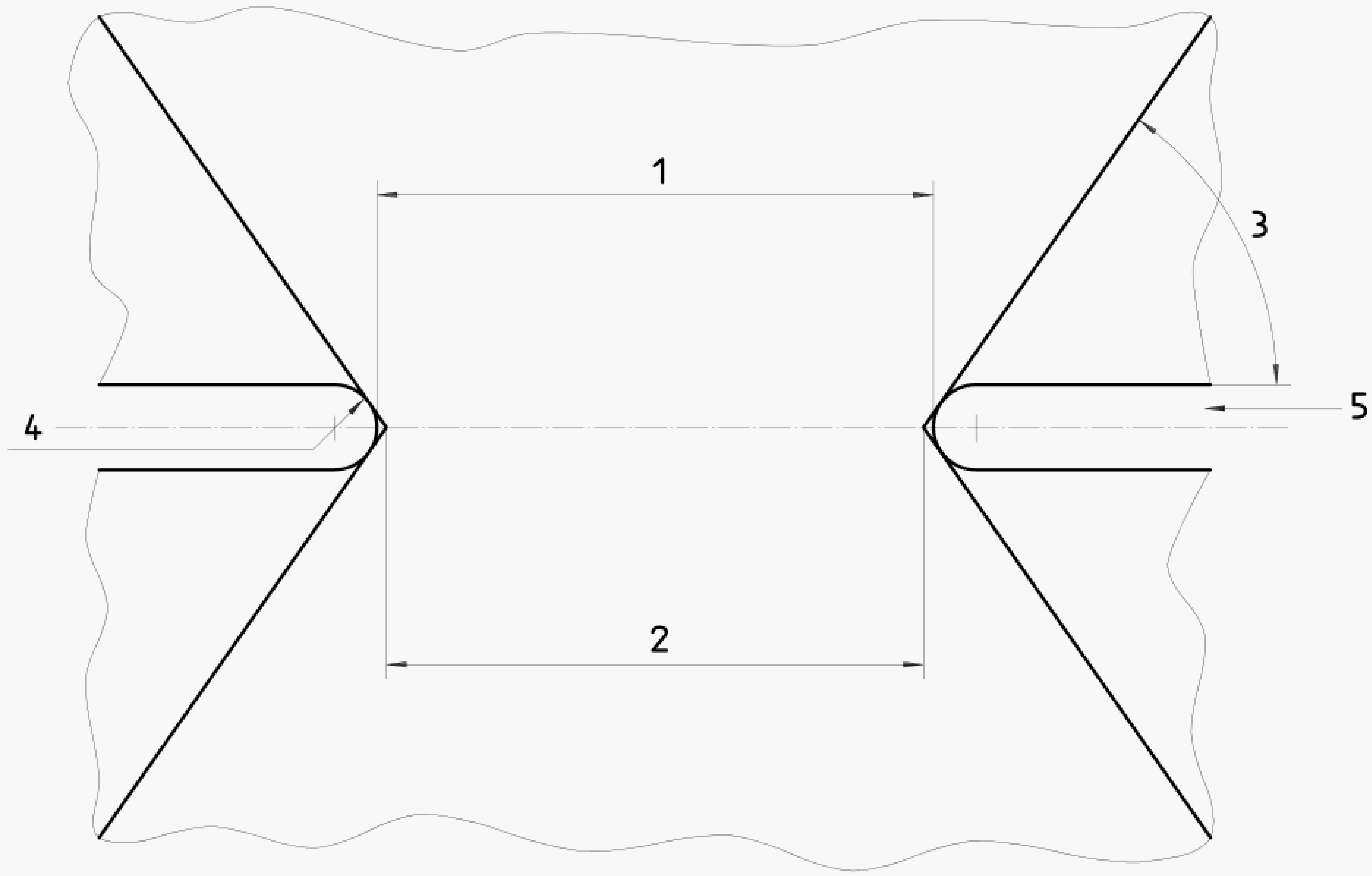
where

F_{ult} is the ultimate load, in newtons;

b is the width of the neck of the test piece, in millimetres;

r is the notch radius, in millimetres;

θ is the winding angle of the reinforcement (see also figure 8), in degrees. If the circumferential reinforcement is provided wholly by non-continuous fibre, take θ to be 90°. If two or more winding angles are used for continuous fibre, take θ as the largest angle used.



Key

1 Width of neck, b (between $4e$ and $5e$)

2 Stressed width, $b + 2r[1 - 1/\sin(\text{winding angle})]$

3 Winding angle

4 Radius within neck of test piece, r

5 Notch

Figure 10 — Detail of the neck

Calculate the average apparent initial circumferential strength, σ_{cF}^*, of the test pieces and, if applicable, the standard deviation.

10 Test report

The test report shall include the following information:

a) a reference to this standard and the referring standard;

b) all details necessary for full identification of the pipe tested;

c) the test method used (i.e. A, B, C, D, E or F);

d) for method A the internal diameter, d_i;

e) for methods B, C, D, E and F the width b of the test piece;

f) for method F the notch radius r;

g) for method F the winding angle θ, if applicable;

h) the number of test pieces;

i) the position in the pipe from which the test pieces were obtained;

j) the temperature during testing;

k) the individual values of the apparent initial circumferential strength, σ_c^*;

l) the average value of the apparent initial circumferential strength and the standard deviation, if applicable;

m) a description of the test pieces after testing;

n) any factors which may have affected the results, such as any incidents or any operating details not specified in this standard;

o) the date of testing.

ICS 23.040.20

Descriptors: piping, pipes (tubes), thermosetting resins, glass reinforced plastics, plastic tubes, tests, tension tests, determination, tensile strength.

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