INTERNATIONAL STANDARD

ISO 8513

Third edition
2016-02-01

Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test methods for the determination of the initial longitudinal tensile strength

Systèmes de canalisations en plastiques — Tubes en plastiques thermodurcissables renforcés de verre (PRV) — Méthodes d'essai pour la détermination de la force en traction longitudinale

Reference number
ISO 8513:2016(E)

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Foreword

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The committee responsible for this document is ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 6, *Reinforced plastics pipes and fittings for all applications*.

This third edition cancels and replaces the second edition (ISO 8513:2014) which has been technically revised.

Introduction

Although this International Standard was revised in 2014, it was found necessary to again revise to correct several small errors in presentation and to revise the allowable testing speed (crosshead movement) range. A review of ISO testing standards for glass-reinforced thermosetting plastics (GRP) materials and the results of a recent testing program indicated that a testing speed of 2 mm/min to 5 mm/min is more appropriate. Also, evidence was presented that method C, the plate method, lead to results that were frequently from shear failures rather than tensile failures and lead to a falsely high prediction of Longitudinal Tensile Strength. Method C has been removed from this edition. Also, the term “Apparent” was removed from the title as it seemed to have no clear meaning.

Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test methods for the determination of the initial longitudinal tensile strength

1 Scope

This International Standard specifies two test methods for determining the longitudinal tensile properties of glass-reinforced thermosetting plastics (GRP) pipes. The properties which can be determined are

— the longitudinal tensile strength, and

— the percentage ultimate elongation.

Method A uses, for the test piece(s), a longitudinal strip cut from a pipe.

Method B uses a specified length of the full cross-section of the pipe.

Method A is applicable to pipes with a nominal size of DN 50 or greater with circumferentially wound filaments, with or without chopped glass and/or woven rovings and/or fillers, and to centrifugally cast pipes. It is applicable to pipes with helically wound filaments with a nominal size of DN 200 or greater.

Method B is applicable to all types of GRP pipe. It is usually used for pipes with a nominal size up to and including DN 150.

Results from one method are not necessarily equal to the results derived from any of the alternative methods. However, all methods have equal validity.

Annex A describes additional considerations for method B that have been found useful for the testing of thin-walled helically wound pipes and can be used to supplement the basic text.

NOTE This International Standard does not address the determination of longitudinal tensile modulus. Due to the multi-layer construction of many GRP pipes, the accurate measurement of strain, necessary for modulus determination, can be very difficult. If it is desired to determine longitudinal modulus, see ISO 527-4 and/or ISO 527-5.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
helical wound
refers to filament-wound pipes made with a balanced winding angle

Note 1 to entry: Sometimes called cross wound.

2.2
longitudinal tensile strength
σ_{LA}^*
σ_{LB}^*
maximum tensile force in the longitudinal direction per unit mean circumference at failure

Note 1 to entry: It is expressed in newtons per millimetre of the circumference (N/mm).

Note 2 to entry: The subscripts A and B denote the method of test used.

2.3
mean circumference
circumference corresponding to the mean diameter multiplied by π (π ≈ 3,141 6)

Note 1 to entry: It is expressed in millimetres.

2.4
mean diameter
d_m
diameter of the circle corresponding with the middle of the pipe wall cross-section

Note 1 to entry: It is given by any of the following:

a) the average of the external diameter of the pipe minus the average of the wall thickness;

b) the external circumference of the pipe divided by π (π ≈ 3,141 6) minus the average of the wall thickness;

c) the average of the internal diameter of the pipe plus the average of the wall thickness.

Note 2 to entry: It is expressed in millimetres.

2.5
ultimate longitudinal tensile stress
$\sigma_{L,ULT}$
maximum longitudinal tensile force per unit cross-sectional area at failure

Note 1 to entry: It is expressed in newtons per square millimetre (N/mm).

2.6
ultimate elongation
ε_L
elongation coincident with the ultimate longitudinal tensile stress

Note 1 to entry: For the purposes of this International Standard, the measurement of elongation is limited to measurement of the movement of the tensile testing machine cross-heads.

Note 2 to entry: It is expressed as a percentage of an initial gauge length or free length of a test piece.

3 Principle

Test pieces comprising either strips cut longitudinally from a pipe wall segment (method A) or a specified length of pipe (method B) are subjected to extension in the longitudinal direction at a constant speed such that fracture occurs within a specified time.

The tensile properties are determined using the initial dimensions of the test piece, the tensile force, and the cross-head movement.

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

a) the methods to be used, i.e. method A or method B;

b) the number of test pieces (see 5.4);

c) if applicable, the requirements for conditioning, e.g. temperature, humidity, time, and associated tolerances (see Clause 6);

d) the test temperature and its tolerance (see Clause 7);

e) the properties to be measured (see Clause 8).

4 Apparatus

4.1 Tensile-testing machine, of the constant rate of cross-head movement type, incorporating the following features:

a) a fixed part, fitted with a grip to hold one end of the test piece without permitting any longitudinal movement thereof, and a moveable part, incorporating a grip to hold the other end of the test piece during extension [the fixed and moving parts and their associated grips (see 4.2) shall enable the test piece to be aligned when a force is applied so that its longitudinal axis coincides with the direction of this force];

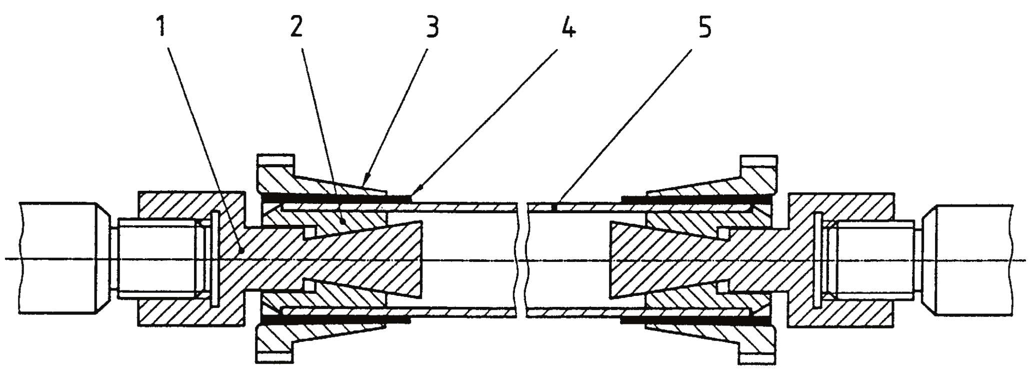
b) a drive mechanism, capable of imparting a constant speed (see 8.3) to the moving part;

c) a force indicator, capable of measuring the force applied to a test piece which is held in the grips (the mechanism shall be free from significant inertia lag at the necessary speed of testing and shall indicate or record force, or consequent stress, with an accuracy of within ±1 % of the value to be measured);

d) a means to measure the cross-head movement as a function of the applied load.

4.2 Grips, for holding the test piece.

Each of the two grips shall be capable of holding one end of the test piece without slip or crushing to an extent that will affect the results obtained. Grips which tighten automatically might be suitable. Typical grips for a pipe section test piece (see 5.3) are shown in Figure 1.



Key

1 mandrel
2 segmented grips
3 sleeve
4 reinforcing band
5 test piece

Figure 1 — Typical grips for a pipe section test piece (method B)

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

5 Test pieces

5.1 General

The test piece shall be a strip or dumbbell conforming to 5.2, or a pipe section conforming to 5.3.

The test piece shall be obtained in such a way that it is not damaged.

The test piece width guidelines might, of necessity, need to be altered for thick wall pipes to smaller values to reflect the testing machine capacity. This is due to some GRP pipes being made in very high thickness to address high pressure and large diameter applications. The testing of such narrower samples will lead to a more conservative indication of strength for thick wall pipes.

For thick wall test pieces, it might also be necessary to clamp the specimen on the cut cross-section sides to allow the specimen to fit into the testing grips.

For pipes with a layered wall construction, it might also be necessary to reinforce the gripped ends to obtain a more even distribution of tensile force.

For pipes reinforced in the axial direction with tapes, fabrics, or mats of a fixed width, it might be necessary to increase the test sample length to ensure that a cross-section with the minimum number of layers of reinforcement (the apparent lowest strength area) falls within the gauge length.

NOTE The test pieces for method A can be cut from a ring previously used for the determination of the initial specific ring stiffness.

5.2 Strip test piece (method A)

5.2.1 Shape

Each test piece shall be a strip cut in the longitudinal direction of the pipe and either shaped to the dimensions of the applicable dumbbell as shown in Figure 2 or a parallel-sided (rectangular) test piece as shown in Figure 3.

5.2.2 Dimensions

5.2.2.1 Length

The length, l, of the test piece shall be (300 ± 15) mm (see Figure 2 and Figure 3).

5.2.2.2 Shaped strip

The gauge length, l_G, of the test piece shall be as follows (see Figure 2):

$$100 \text{ mm} \leq l_G \leq 150 \text{ mm} \quad (1)$$

The radius, R, shall be machined to conform to the following limits (see Figure 2):

$$50 \text{ mm} \leq R \leq 70 \text{ mm} \quad (2)$$

The width, b_G, of the test piece within the gauge length shall conform to the following requirements (see Figure 2 and 5.2.1):

$$b_G = (10 \pm 1) \text{ mm for DN} \leq 150 \quad (3)$$

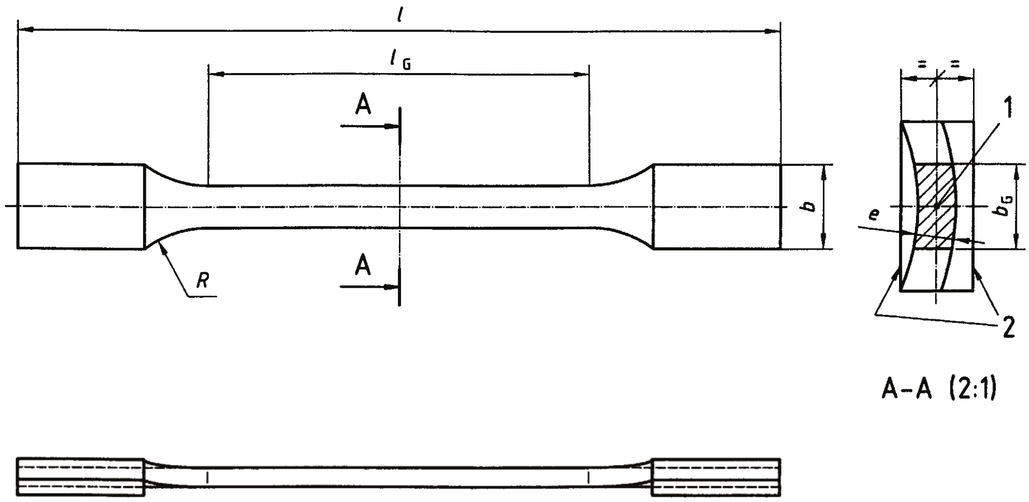
$$b_G = (25 \pm 1) \text{ mm for DN} > 150 \quad (4)$$

The total width, b, of the test piece shall conform to the following requirements (see Figure 2):

$$b = (18 \pm 2) \text{ mm for DN} \leq 150 \quad (5)$$

$$b = (40 \pm 2) \text{ mm for DN} > 150 \tag{6}$$

The above width guidelines might need to be reduced to accommodate thick wall pipes (see 5.1).



Key

1 centroid of gauge length cross-section
2 ends built up with plain or reinforced thermoset resin and trimmed flat and parallel, if required
e wall thickness
l test sample length
l_G gauge length
b total test sample width
b_G width of gauge length
R radius

Figure 2 — Shaped test piece dimensions (method A)

5.2.2.3 Parallel-sided strip

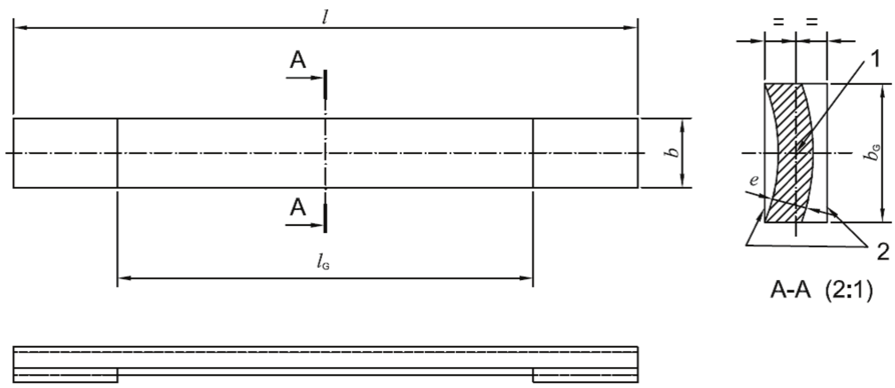
The width, b_G, of the test piece within the gauge length shall conform to the following requirements (see Figure 3). The gauge length, l_G, shall be the non-built up area between the grips.

The width, b (equal to the gauge width b_G), of the test piece shall be as follows (see Figure 3):

$$b_G = (10 \pm 1) \text{ mm for DN} \leq 150 \tag{7}$$

$$b_G = (25 \pm 1) \text{ mm for DN} > 150 \tag{8}$$

The above width guidelines might need to be reduced to accommodate thick wall pipes (see 5.1).



Key

1 centroid of gauge length cross-section

2 ends built up with plain or reinforced thermoset resin and trimmed flat and parallel, if required

e wall thickness

l test sample length

l_G gauge length

b test sample width = gauge width b_G

Figure 3 — Parallel-sided strip test piece dimensions (method A)

5.2.3 Use of built-up ends

Unless grips (see 4.2) with close-fitting curved jaws are to be used, and if the manufacturer elects to utilize built-up ends, build up the thickness of the test piece ends over the grip length with a suitable 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 Figure 2 and Figure 3) will lie on the loading centreline of the testing machine when gripped.

5.3 Pipe section test pieces (method B)

Each test piece (see Figure 1) shall be a full section of the pipe with a minimum length of 450 mm

5.4 Number of test pieces

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

6 Conditioning

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

7 Test temperature

Conduct the applicable procedure given in Clause 8 at the temperature specified in the referring standard.

8 Procedure (methods A and B)

8.1 For a strip test piece (method A), measure and record to the nearest 0,1 mm the wall thickness e and the widths b and b_G, as applicable, of the test piece, at the centre of the gauge length.

For a pipe test piece (method B), measure and record either the internal or the external diameter and the average wall thickness of the test piece by taking three measurements equally spaced around the circumference at both ends of the pipe section.

8.2 Place the test piece in the tensile-testing machine (4.1) so that the axial alignment coincides with the direction of pull and clamp the grips (4.2) uniformly and sufficiently tight to prevent slipping of the test piece.

8.3 Load the test piece by separating the grips at a constant speed of between 2 mm/min to 5 mm/min and record forces and corresponding elongations at appropriate intervals. Record the maximum force sustained by the test piece, in newtons.

8.4 Discard any test pieces which have slipped in the grips and those for which rupture has occurred outside the gauge length, and repeat the test(s) on a corresponding number of test pieces conforming to 5.2, 5.3 or 5.4.

NOTE If failures occur outside the gauge length, it is allowed to include such failures if the resulting average strength is increased.

9 Calculation

9.1 For strip test pieces (method A)

9.1.1 For each test piece, calculate the initial longitudinal tensile strength, $\sigma_{LA,i}$*, in N/mm of the circumference, using Formula (9):

$$\sigma_{LA,i}{}^* = \frac{F}{b_G} \qquad (9)$$

where

F is the maximum force in N;

b_G is the gauge width of the test piece, in mm;

i is the number of the test piece.

Calculate the average initial longitudinal tensile strength, $\sigma_{LA,i}$*, of the test pieces and, if applicable, the standard deviation.

9.1.2 For each test piece, calculate the percentage ultimate elongation. For all the test pieces, determine the average percentage ultimate elongation and the standard deviation, if applicable.

9.2 For pipe test pieces (method B)

9.2.1 For each test piece, calculate the initial longitudinal tensile strength, $\sigma_{LB,i}$*, in N/mm of the circumference, using Formula (10):

$$\sigma_{\mathrm{LB},i}{}^{*} = \frac{F}{\pi \times d_{\mathrm{m}}} \tag{10}$$

where

F is the maximum force, in N;

d_{m} is the mean diameter (see 2.4), in mm;

i is the number of the test piece.

Calculate the average initial longitudinal tensile strength, σ_{LB}*, of the test pieces and, if applicable, the standard deviation.

9.2.2 For each test piece, calculate the percentage ultimate elongation, $\varepsilon_{\mathrm{L},i}$. For all the test pieces, determine the average percentage ultimate elongation, ε_{L}, and the standard deviation, if applicable.

10 Test report

The test report shall include the following information:

a) a reference to this International Standard, i.e. ISO 8513:2016, and to the referring standard;

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

c) the test method used, i.e. method A or method B;

d) in the case of a strip test piece, whether it was parallel-sided or shaped and whether or not the ends were built-up;

e) the average wall thickness and the length of each test piece and other relevant dimensions, as applicable;

f) the number of test pieces;

g) the positions in the pipe from which the test pieces were obtained;

h) the temperature during the test;

i) the rate of loading;

j) the elapsed time to failure;

k) the individual value(s) for the initial longitudinal tensile strength and/or the ultimate longitudinal tensile stress, the average value and, if applicable, the standard deviation;

l) the individual percentage ultimate elongation and the gauge length over which the elongation was measured and the average percentage ultimate elongation and, if applicable, the standard deviation;

m) the results of any load/elongation in either graphical or numerical form;

n) a description of the appearance of the test pieces after testing;

o) any factors which might have influenced the results, such as any incidents or operating details not specified in this International Standard;

p) the date of the test.

Annex A
(informative)

Determination of longitudinal properties for helically filament-wound thin wall pipe

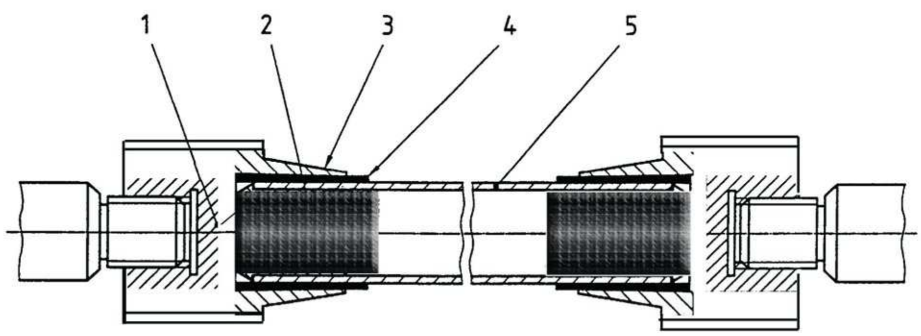
A.1 General

This Annex can be useful for the determination of longitudinal tensile properties of helical filament wound small-diameter thin wall pipe tested by method B. Only those exceptions or additions to the base standard are addressed in this Annex.

A.2 Method B

Testing of thin wall pipe can lead to bucking of the pipe before longitudinal tensile failure. Therefore, an internal “core” support can be used to prevent bucking failure (see Figure A.1)

Obtaining a tight grip on a thin wall pipe can be difficult and reinforcing the gripped area with metallic tabs cut from a section of aluminium pipe has been found effective in preventing grip failures. The tabs are bonded to the test specimen using glass fibre fabric tape and thermosetting resin. A typical example to illustrate preparation of metal tabs is shown in Figure A.2. An example of the application of the fabric tape is shown in Figure A.3. The suggested boundary configuration, which is to taper the tape build up over approximately 30 mm, is shown in Figure A.4.



Key

1 core

2 segmented grips

3 sleeve

4 reinforcing band (metallic)

5 test piece

Figure A.1 — Typical grips for a pipe section test piece

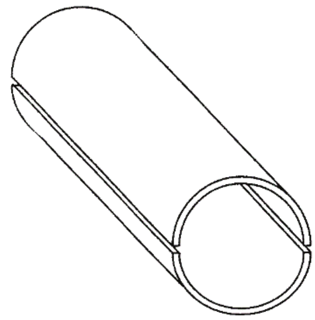


Figure A.2 — Preparation of metallic tabs

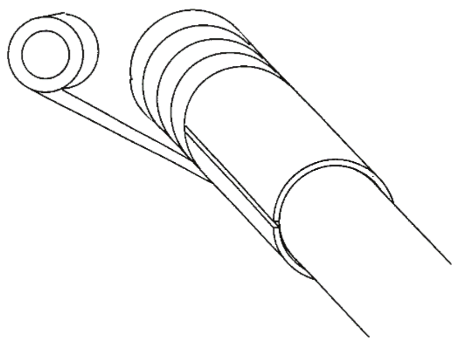
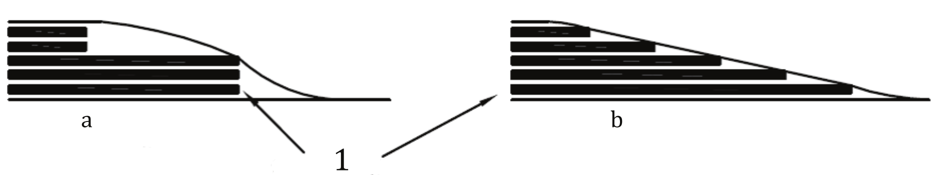


Figure A.3 — Winding tape over the tabs



Key

1 fabric material

a Not recommended.

b Recommended.

Figure A.4 — Suggested configuration of the boundary between tab and cylinder

Bibliography

[1] ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

[2] ISO 527-5, *Plastics — Determination of tensile properties — Part 5: Test conditions for unidirectional fibre-reinforced plastic composites*

ICS 23.040.20
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