INTERNATIONAL STANDARD

ISO 10471

Second edition
2018-05

Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the long-term ultimate bending strain and the long-term ultimate relative ring deflection under wet conditions

Tubes en plastiques thermodurcissables renforcés de verre (PRV) — Détermination de l'effort à la flexion ultime à long terme et réflexion annulaire relative ultime à long terme dans des conditions mouillées

Reference number
ISO 10471:2018(E)

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Published in Switzerland

Contents

Page

Foreword

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

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

This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 6, *Reinforced plastics pipes and fittings for all applications*.

This second edition cancels and replaces the first edition (ISO 10471:2003), which has been technically revised. It also incorporates the Amendment ISO 10471:2003/Amd1:2010.

The major changes to this edition include:

— reference to ISO 3126 for dimension measurement;

— clarification of accuracy statements;

— inclusion of calculation procedure for spring-line failures.

Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the long-term ultimate bending strain and the long-term ultimate relative ring deflection under wet conditions

1 Scope

This document specifies a method for determining by extrapolation the long-term ultimate ring bending strain and the calculation of the long-term ultimate relative ring deflection of glass-reinforced thermosetting plastics (GRP) pipes, under wet conditions.

Two methods of loading are given, one using plates the other beam bars.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

3 Terms and definitions

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

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

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

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

3.1
vertical compressive force
F
vertical force, applied to a horizontal pipe to cause a vertical deflection

Note 1 to entry: Vertical compressive force is expressed in newtons.

3.2
mean diameter
d_m
diameter of the circle corresponding with the middle of the pipe wall cross-section and given by either of the following formulae:

$$d_m = d_i + e$$

$$d_m = d_e - e$$

where

d_i is the internal diameter, in metres (m);

d_e is the external diameter, in metres (m);

e is the wall thickness of the pipe, in metres (m).

Note 1 to entry: Mean diameter is expressed in metres.

3.3
vertical deflection
y
vertical change in diameter of a pipe in a horizontal position in response to a *vertical compressive force* (3.1)

Note 1 to entry: Vertical deflection is expressed in metres.

3.4
relative vertical deflection
y/d_m
ratio of the *vertical deflection*, y (3.3), to the *mean diameter* (3.2) of the pipe, d_m

3.5
ultimate vertical deflection under wet conditions
$y_{u, wet}$
vertical deflection (3.3) of the pipe, y, when failure occurs under wet conditions (see Clause 4)

Note 1 to entry: Ultimate vertical deflection under wet conditions is expressed in metres.

3.6
ultimate relative vertical deflection under wet conditions
$y_{u, wet}/d_m$
ratio of the *ultimate vertical deflection under wet conditions*, $y_{u, wet}$ (3.5), to the *mean diameter* (3.2) of the pipe, d_m

3.7
long-term ultimate ring deflection under wet conditions
$y_{u, wet, x}$
extrapolated value of the *ultimate vertical deflection under wet conditions* (3.5) of the pipe, $y_{u, wet}$, when failure is expected to occur at a time, x, specified in the referring standard

Note 1 to entry: Long-term ultimate ring deflection under wet conditions is expressed in metres.

3.8
long-term ultimate relative ring deflection under wet conditions
$y_{u, wet, x}/d_m$
ratio of the long-term *ultimate ring deflection under wet conditions* (3.7) of the pipe, $y_{u, wet, x}$, to the *mean diameter* (3.2) of the pipe, d_m

3.9
failure
loss of the structural integrity of a test piece as evidenced by the inability of the test piece to carry the load

3.10
time to failure
t_u
time elapsed until *failure* (3.9) occurs

Note 1 to entry: Time to failure is expressed in hours.

3.11
specific ring stiffness
S
physical characteristic of a pipe, that is a measure of the resistance to ring deflection per metre length under external load and is defined by the following formulae

$$S = \frac{E \times I}{d_m^3}$$

where

E is the apparent modulus of elasticity, in newtons per square metre, determined by testing in accordance with ISO 7685;

I is the second moment of area in the longitudinal direction per metre length, in metres to the fourth power per metre (m^4/m), i.e.

$$I = \frac{e^3}{12}$$

where

e is the wall thickness of the pipe, in metres (m);

d_m is the mean diameter of the pipe, in metres (m) (see 3.2).

Note 1 to entry: Specific ring stiffness is expressed in newtons per square metre.

3.12
initial specific ring stiffness
S_0
value of *specific ring stiffness* S (3.11), determined by testing in accordance with ISO 7685

Note 1 to entry: Initial specific ring stiffness is expressed in newtons per square metre.

3.13
strain factor
D_g
dimensionless factor used to transform a deflection value into a strain value

4 Principle

Each of several cut lengths of pipe is supported horizontally and loaded throughout its length to compress it diametrically to achieve a desired level of strain. The force application surfaces are either bearing plates or beam bars.

The pipe is immersed in water at a given temperature for a period of time during which the force remains constant and the increasing vertical deflection is measured at intervals until failure (see 3.9) occurs. The relative vertical deflection at failure [ultimate relative vertical deflection, $y_{u,\,wet}/d_m$ (see 3.6)] is converted into a bending strain at failure (ultimate bending strain, $\varepsilon_{u,\,wet}$, in percent), either calculated using Formula (1) or determined from a strain-deflection calibration curve (see 10.3).

The strain may also be measured directly by the use of waterproofed strain gauges.

The following strain calculations assume that the neutral axis is at the pipe wall midpoint. For pipe wall constructions that produce an altered neutral axis position, it is necessary to evaluate results by substituting $2\bar{y}$ for the wall thickness e where $\bar{y}$ is the distance from the appropriate pipe surface to the neutral axis. The neutral axis position shall be determined using an appropriate method, e.g. calculation or use of strain gauge couples.

$$\varepsilon_{\text{u,wet}} = D_{\text{g}} \times \frac{e}{d_{\text{m}}} \times \frac{y_{\text{u,wet}}}{d_{\text{m}}} \times 100 \tag{1}$$

where for crown or invert failures:

D_{g} is calculated using Formula (2):

$$D_{\text{g}} = \frac{4{,}28}{\left(1 + \frac{y_{\text{u,wet}}}{2 \times d_{\text{m}}}\right)^2} \tag{2}$$

where for spring line failures:

D_{g} is calculated using Formula (3):

$$D_{\text{g}} = \frac{2{,}44}{\left(1 + \frac{y_{\text{u,wet}}}{2 \times d_{\text{m}}}\right)^2} \tag{3}$$

where

$y_{\text{u, wet}}$ is the ultimate vertical deflection under wet conditions, in metres (m);

d_{m} is the mean diameter of the pipe (see 3.2), in metres (m);

e is the mean wall thickness of the pipe at crown, invert or spring-lines as appropriate, in metres (m).

These values of ultimate bending strain and the applicable times, t_{u} (see 3.10), are used in the procedures described in ISO 10928 to determine the long-term ultimate bending strain under wet conditions, $\varepsilon_{\text{u, wet, x}}$.

It is assumed that values for the following test parameters will be set by the referring standard:

a) the time, x, to which the values are to be extrapolated (see 3.7 and 3.8);

b) the test temperature (see 5.3 and 10.1);

c) the length and number of test pieces (see Clauses 6 and 7);

d) the distribution of the times to failure (see 10.8);

e) the pH of the test water.

This standard test procedure is to determine and analyse the bending strains induced by the vertical deflections. This procedure accommodates sample to sample variation and results in a strain versus time expression applicable to a range of pipe classifications.

5 Apparatus

5.1 Compressive loading machine

The machine shall comprise a system capable of applying a force, without shock, through two parallel force application surfaces in accordance with 5.2 so that a horizontally orientated test piece of pipe in accordance with Clause 6 and immersed in water can be compressed vertically and maintained under a constant force for the duration of the test in accordance with 10.7.

Ensure that the applied force is not affected by buoyancy effects or friction.

For test pieces subjected to high forces, for which failure is expected to occur within 100 h, an automatic recording device can help in recording failure times and deflections accurately. Such devices are useful for all test samples.

5.2 Force application surfaces

5.2.1 General arrangement

The method allows the use of either bearing plates or beam bars for loading the test piece, subject to reporting the choice used. Either method may be used for measurements of relative vertical deflection up to 28 %. When it is expected that 28 % deflection is going to be exceeded then the procedure is limited to the use of at least one beam bar.

The surfaces shall be provided by a pair of bearing plates, in accordance with 5.2.2, or a pair of beam bars, in accordance with 5.2.3, or a combination of one such plate and one such bar. However, if the applied force is expected to cause a relative deflection in excess of 28 %, at least one of the surfaces shall be a beam bar. The surface's major axes shall be perpendicular to and centred on the direction of application of force F by the compressive loading machine, as shown in Figure 1. The surfaces to be in contact with the test piece shall be flat, smooth, clean and parallel.

5.2.2 Plates

The plate(s) shall have a width of at least 100 mm and a length at least equal to the length of the test piece (see Clause 6). They shall be sufficiently stiff so that they do not visibly bend or otherwise deform during the test.

5.2.3 Beam bars

Each beam bar shall be sufficiently stiff that it does not visibly bend or otherwise deform during the test. Each beam bar shall have a length at least equal to the length of the test piece (see Clause 6) and a flat face (see Figure 1) without sharp edges. The width of the flat face shall be 15 mm to 55 mm.

The beam bars shall be constructed and supported so that no other surface of the beam bar structure comes into contact with the test piece during the test.

5.3 Water container

A container large enough is required to accommodate submerged test pieces in accordance with Clause 6 while they are subject to the compressive force in accordance with 10.6 and containing test water maintained at the specified temperature (see Clause 4).

The water level shall be maintained sufficiently constant to avoid any significant effect on the value of the vertical force applied to the test piece.

5.4 Measuring devices

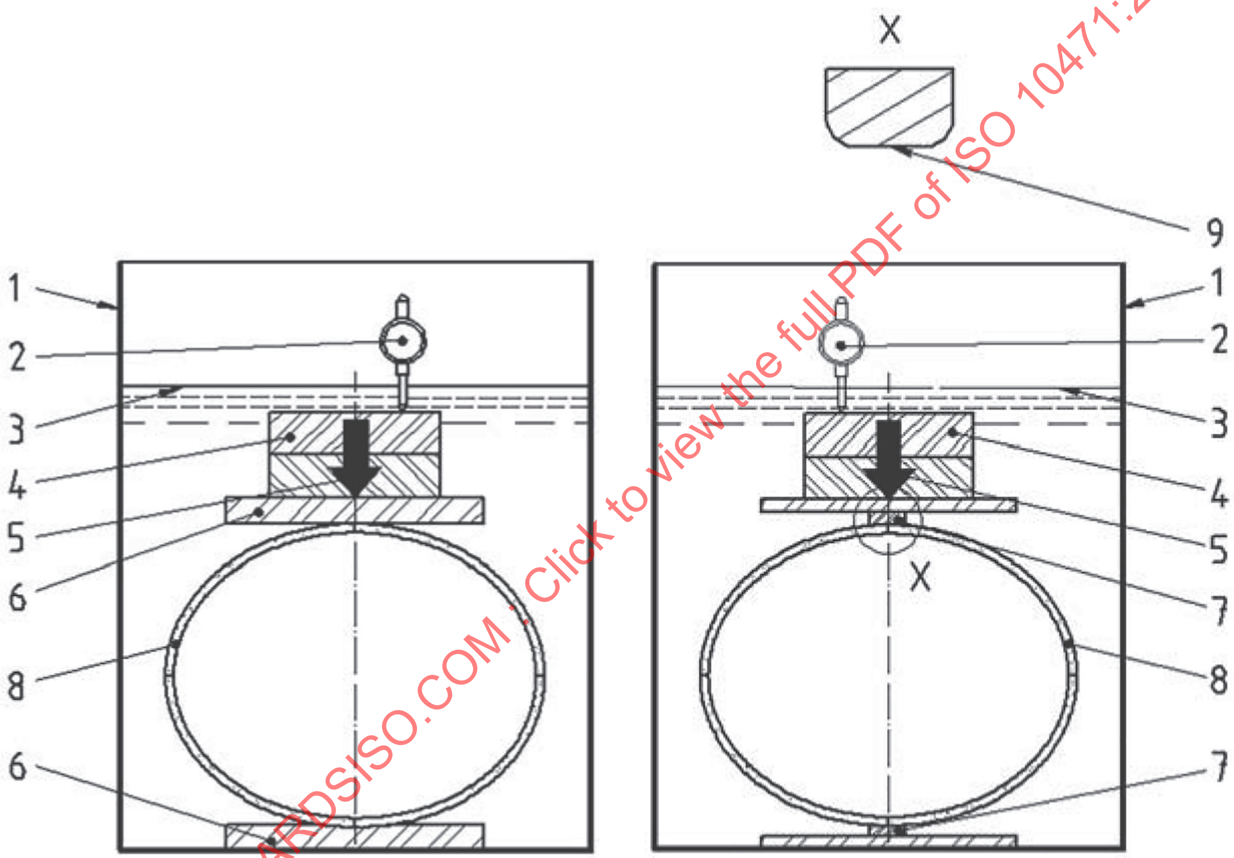
The requirements for the measuring devices are as follows:

a) The devices used to measure dimensions (length, diameter, wall thickness) as specified in Clause 8 shall have a calibrated accuracy of within ±1 % of the dimension being measured.

b) The devices used to measure deflection of the test piece in the vertical direction during the test shall have a calibrated accuracy of within ±1 % of the initial deflection value.

c) The devices used to measure load shall have a calibrated accuracy of ±1 % of the value applied.

When selecting the device to measure the change in diameter of the test piece, consideration should be given to the potentially corrosive environment in which the device is to be used.



a) Plate loading b) Beam bar loading

Key

1 water container
2 deflection-measuring device
3 water level
4 dead-weights
5 direction of compressive force, *F*
6 bearing plate
7 beam bar
8 test piece
9 flat face

Figure 1 — Typical test arrangements

6 Test piece

The test piece shall be a complete pipe ring. The length, L, in metres, of the test piece shall be as specified in the referring standard, subject to permissible deviations of ±5 %. If not specified in the referring standard, the length of the test piece shall be (300 ± 15) mm.

The ends shall be smooth, shall be cut perpendicular to the axis of the pipe and may be sealed.

Four straight lines shall be drawn on either the inside or the outside along the length of the test piece at 90° to each other, to serve as reference lines.

7 Number of test pieces

Unless otherwise specified in the referring standard, at least 18 test pieces shall be used to obtain the distribution of failure times specified in the referring standard (see the numbered list in Clause 4).

8 Determination of the dimensions of the test piece

8.1 Length

Measure the length of each test piece along each reference line in accordance with ISO 3126. Trim or replace, as applicable, the test piece if it does not conform.

Calculate the mean length, L, in metres, of each test piece from the six measured values.

8.2 Wall thickness

Measure in accordance with ISO 3126 the wall thickness of each test piece at four equally spaced locations on each reference line.

For each reference line, calculate the mean wall thickness, e, in metres, of the four measured values.

Calculate the sample mean wall thickness using all thickness values.

8.3 Mean diameter

Measure in accordance with ISO 3126 either the internal or external diameter (see 3.2).

Using either Formula (1) or Formula (2), calculate the mean diameter, d_m (see 3.2), of the test piece using the value obtained for the sample mean wall thickness, e, in 8.2.

9 Conditioning

If applicable, condition the test pieces in accordance with the referring standard.

10 Procedure

10.1 For each test piece conduct the following procedure at the temperature specified in the referring standard (see Clause 4).

10.2 To assess the uniformity of the test pieces, determine and record in accordance with the constant load procedures in ISO 7685 the initial specific ring stiffness, S_0, of each test piece. The measured value of S_0 at the pair of reference lines (see Clause 6) may also be used to estimate the force required to compress the test piece to the necessary deflection to achieve a time to failure that, together with those produced from other test pieces, conforms to the distribution of times to failure specified in the referring standard.

10.3 Deflections in excess of 28 % of the diameter may cause local flattening of the pipe and lead to erratic test results. For deflections approaching 28 %, improved accuracy is obtained by use of strain gauges to establish, for each pipe product, a calibration scale of deflection versus measured strain. This calibration technique is useful at all deflection levels. If such a calibration procedure is established then it shall be used to determine the strains for all test pieces in the test series.

10.4 Place a test piece in the apparatus in contact with the upper and lower plate or beam bar with the pair of diametrically opposed reference lines vertically aligned. However, if the applied force is expected to result in relative deflections that can be in excess of 28 %, use at least one beam bar. Ensure that the contact between the test piece and each bearing plate or beam bar is as uniform as possible and the plates and/or beam bars are not tilted laterally. Place the apparatus in the water container.

10.5 Fill the container with water so that the test piece is fully immersed.

10.6 When the test piece is fully immersed in the water and taking account, as necessary, of the weight of the upper plate or beam bar, and of any spacer, apply the vertical compressive force, *F*, so that the corresponding vertical deflection is reached within 3 min and record the actual force applied and deflection achieved.

10.7 While maintaining the force applied in 10.6, measure and record at predetermined intervals of time the elapsed time and the deflection of the test piece, using either suitable manual devices or automatic recording equipment. When failure (see 3.9) occurs, the time to failure, t_u, and the deflection at failure, y_u, wet, shall be taken as:

a) either the elapsed time and its associated deflection recorded on the automatic device (the preferred, recommended and most accurate method);

b) or the last recorded readings, prior to failure occurring, of deflection and its associated time.

NOTE Table A.1 gives values of equal lg (time in h) increments which can be useful to the operator.

10.8 Continue the procedure detailed in 10.2 to 10.7 inclusive until at least 18 test pieces have failed with the distribution of times to failure specified in the referring specification. However, if 16 test pieces have failed and two others have been on test for more than 10 000 h without failing, then these two test pieces may be included in the data at their current elapsed time and deflection if it provides sufficient data for extrapolation and the distribution of failure times required by the referring standard will be satisfied.

10.9 Convert the relative vertical deflection at failure [ultimate relative vertical deflection, $y_{u,\ wet}/d_m$ (see 3.6)] determined in accordance with 10.7 and 10.8 into a bending strain at failure (ultimate bending strain), $\varepsilon_{u,\ wet}$, in percent, using Formulae (1) and (2) or (3) as appropriate or as determined by deflection-strain calibration.

11 Calculation

11.1 Extrapolation of the strain data to obtain the x-year value, $\varepsilon_{x,\ wet}$

Determine lg (time to failure in h), t_u (see 3.10), and lg (bending strain at failure in percent) from the series of calculated bending strains at failure and their associated times obtained in accordance with 10.9.

From this data, determine, in accordance with ISO 10928, the formula of the strain regression line. Using this formula, calculate the extrapolated long-term ultimate bending strain under wet conditions at x years, lg ($\varepsilon_{u,\ wet,\ x}$) and then the long-term ultimate bending strain, $\varepsilon_{u,\ wet,\ x}$, in percent.

