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

Tubes en plastiques thermodurcissables renforcés de verre (PRV) — Détermination de la rigidité annulaire spécifique à long terme en relaxation, en conditions mouillées, et calcul du facteur de relaxation au mouillé

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Foreword

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ISO 14828 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*.

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

1 Scope

This International Standard specifies a method for determining both the long-term specific ring relaxation stiffness and the wet relaxation factor for glass-reinforced thermosetting plastics (GRP) pipes.

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

ISO 10928:1997, *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 International Standard the following definitions apply:

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

3.2
specific ring stiffness
S
physical characteristic of a pipe, expressed in newtons per square metre, that is a measure of the resistance to ring deflection per metre length under external load and is defined by Equation (1):

$$S = \frac{E \times I}{d_m^3} \quad (1)$$

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.

$$I = \frac{e^3}{12} \quad (2)$$

e being the wall thickness of the pipe, in metres;

d_m is the mean diameter of the pipe, in metres (see 3.3).

3.3
mean diameter
d_m
diameter, expressed in metres, of the circle corresponding with the middle of the pipe wall cross-section and given by either of the following equations:

$$d_m = d_i + e \quad (3)$$

$$d_m = d_e - e \quad (4)$$

where

d_i is the internal diameter, in metres;

d_e is the external diameter, in metres;

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

3.4
initial specific ring stiffness
S_0
value of S, expressed in newtons per square metre, determined by testing in accordance with ISO 7685

3.5
long-term specific ring relaxation stiffness at position 1
$S_{x,\,1,\,\text{relax, wet}}$
value of S, expressed in newtons per square metre, at a reference position, position 1 (see 10.2), at x years, obtained by extrapolation of long-term force measurements at a constant deflection under wet conditions (see 3.2 and 10.2)

3.6
calculated long-term specific ring relaxation stiffness under wet conditions
$S_{x,\,\text{relax, wet}}$
calculated value of S, expressed in newtons per square metre, at x years obtained using Equation (5):

$$S_{x,\,\text{relax, wet}} = S_0 \times \alpha_{x,\,\text{relax, wet}} \quad (5)$$

where

x is the elapsed time, in years, specified in the referring standard;

$\alpha_{x,\,\text{relax, wet}}$ is the wet relaxation factor (see 3.7);

S_0 is the initial specific ring stiffness, in newtons per square metre.

3.7
wet relaxation factor
$\alpha_{x,\,\text{relax, wet}}$
ratio of the long-term specific ring relaxation stiffness to the initial specific ring stiffness, both at a reference position, position 1 (see 10.2), and given by Equation (6):

$$\alpha_{x,\,\text{relax, wet}} = \frac{S_{x,\,1,\,\text{relax, wet}}}{S_{0,\,1}} \quad (6)$$

where

$S_{0,\ 1}$ is the initial specific ring stiffness at position 1, in newtons per square metre, determined in accordance with ISO 7685;

$S_{x,\ 1,\ \mathrm{relax,\ wet}}$ is the long-term specific ring relaxation stiffness at position 1, in newtons per square metre

3.8
vertical deflection
y
vertical change in diameter of a pipe in a horizontal position, expressed in metres, in response to a vertical compressive force (see 3.1)

3.9
long-term applied force
$F_{x,\ 1,\ \mathrm{wet}}$
value of the force F, expressed in newtons, at the reference position, position 1 (see 10.2), at x years obtained by extrapolation of long-term applied-force measurements at a constant deflection under wet conditions (see 3.1 and 10.2)

3.10
deflection coefficient
f
dimensionless factor which takes into account general second-order theory as applied to deflection and is given by Equation (7):

$$f = \left[1\,860 + \left(2\,500 \times y_1 / d_{\mathrm{m}}\right)\right] \times 10^{-5} \quad (7)$$

where

y_1 is the vertical deflection at position 1, in metres;

d_{m} is the mean diameter (see 3.3) of the pipe, in metres.

3.11
calculated strain
$\varepsilon_{\mathrm{calc,\ 1}}$
strain on the inner surface at the crown and invert of a pipe at the reference position, position 1, given in percent by Equation (8):

$$\varepsilon_{\mathrm{calc,\ 1}} = \frac{4{,}28 \times \dfrac{e}{d_{\mathrm{m}}} \times \dfrac{y_1}{d_{\mathrm{m}}} \times 100}{\left(1 + \dfrac{y_1}{2 \times d_{\mathrm{m}}}\right)^2} \quad (8)$$

where

y_1 is the vertical deflection at position 1, in metres;

d_{m} is the mean diameter of the pipe (see 3.3), in metres;

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

4 Principle

A cut length of pipe supported horizontally is loaded throughout its length to compress it diametrically to a prescribed level of strain calculated using Equation 8. 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 vertical deflection remains constant and the force is measured at intervals. The long-term force is estimated by extrapolation. From this force and the deflection, the long-term specific ring relaxation stiffness under wet conditions is calculated.

The wet relaxation factor is then determined from the long-term specific ring relaxation stiffness and the initial specific ring stiffness of the same test piece. The declared wet relaxation factor is the average of the results from two test pieces.

NOTE It is assumed that values for the following test parameters will be set by the standard making reference to this International Standard:

a) the method for measuring the initial specific ring stiffness, i.e. method A or B of ISO 7685:1998 (see 3.4);

b) the time to which the values are to be extrapolated (see 3.6 and 11.1);

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

d) the length of the test piece (see Clause 6);

e) if applicable, the conditioning parameters, i.e. temperature, humidity and duration (see Clause 9);

f) the time limits for maintaining the test piece under load (see 10.6);

g) the level of strain at which the test is to be conducted.

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 conforming to 5.2 so that a horizontally orientated test piece of pipe conforming to Clause 6 and immersed in water can be compressed vertically and maintained at a constant deflection for the duration of the test in accordance with 10.6.

The machine shall include equipment, such as a load cell (see 5.4), for measuring the force applied to within ± 1 % of the maximum measured force for the duration of the test.

Ensure that the applied force takes into account buoyancy effects and is not affected by friction.

5.2 Force application surfaces

The method allows the use of either bearing plates or beam bars for loading the test piece, subject to reporting the choice used. The same loading arrangement (plates, bars, or plate and bar) shall be used for the determination of both initial and long-term stiffness.

5.2.1 General arrangement

The surfaces shall be provided by a pair of plates, conforming to 5.2.2, or a pair of beam bars, conforming to 5.2.3, or a combination of one such plate and one such bar, with their major axes perpendicular to and centred on the direction of application of force F exerted 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 so constructed and supported that no other surface of the beam bar structure comes into contact with the test piece during the test.

5.3 Water container

Required is a container large enough to accommodate submerged test pieces conforming to Clause 6 whilst they are subject to the compressive force in accordance with 10.6 and containing tap water having a pH of 7 ± 2 and kept at the specified temperature (see 10.1).

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

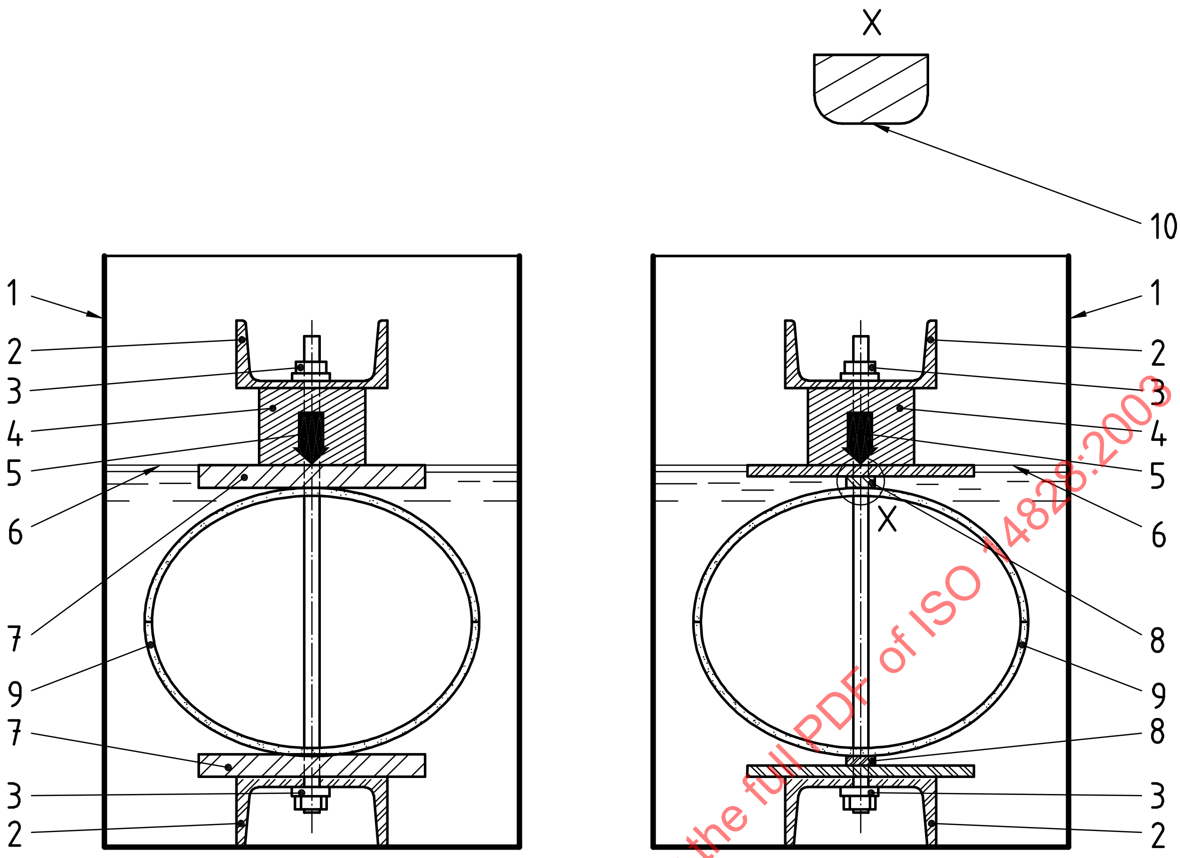
Required are devices capable of determining:

a) the necessary dimensions (length, diameters, wall thickness) to an accuracy within that specified in Clause 8, as applicable;

b) the change in the force applied to the test piece in the vertical direction during the test to an accuracy within ± 1,0 % of the initial value;

c) the deflection of the test piece in the vertical direction during the test to an accuracy within ± 1,0 % of the initial value.

NOTE When selecting the device to measure the change in force applied to 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 compression frame
3 locking nut
4 load cell
5 vertical compressive force, F
6 water level
7 bearing plate
8 beam bar
9 test piece
10 flat face

Figure 1 — Typical test arrangements

6 Test piece

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

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

Straight lines shall be drawn on the inside or the outside along the length of the test piece and repeated at 60° intervals around its circumference, to serve as reference lines.

7 Number of test pieces

Two test pieces shall be used (see also 11.3).

8 Determination of the dimensions of the test pieces

8.1 Length

Measure the length of each test piece along each reference line with an accuracy within ± 1,0 % to determine whether or not the test piece conforms to Clause 6. 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 to within ± 0,2 mm the wall thickness of each test piece at each end of each reference line.

Calculate the mean wall thickness, e, in metres, of the 12 measured values.

8.3 Mean diameter

Measure to an accuracy within ± 0,5 mm either of the following:

a) the internal diameter, d_i, of the test piece between each diametrically opposed pair of reference lines at their mid-length, e.g. by means of calipers, subsequently calculating the mean internal diameter, in metres, of the six measured values;

b) the external diameter, d_e, in metres, of the test piece by means of a circumferential wrap steel tape.

Using either Equation (3) or Equation (4), calculate the mean diameter, d_m (see 3.3), of the test piece using the value obtained for the mean wall thickness, e, in 8.2 and either the mean internal or the external diameter.

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.

10.2 Determine and record in accordance with ISO 7685 the initial specific ring stiffness, S_0, of the test piece. Use the measured value of S_0 at a pair of reference lines, to be designated "position 1", to estimate the force required to compress the test piece to the necessary deflection within 3 min to achieve, unless specified otherwise in the referring standard, a calculated strain (see 3.11) between 0,35 % and 0,4 %.

10.3 Place the test piece in the apparatus in contact with the upper and lower plate or beam bar, with the pair of diametrically opposed reference lines designated "position 1", in accordance with 10.2, vertically aligned. 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.

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

10.5 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, apply the vertical compressive force, F, estimated in accordance with 10.2 so that the corresponding vertical deflection is reached within 3 min and record the actual force applied and deflection achieved.

10.6 Hold the deflection constant throughout the duration of the test. Commencing at not more than 1 h after loading and continuing for more than 10 000 h, measure and record, to within 2 % of the initial value, the force applied to the test piece at approximately equal intervals of lg(time) after loading. The intervals shall be such that ten approximately equally spaced readings are taken for each decade of lg(time in h).

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

11 Calculation

11.1 Extrapolation of the loading data

If required by the referring standard, use the data obtained in accordance with 10.6, and plot lg(load) as a function of lg(time in h).

From the measured loads and corresponding time intervals between 1 h and over 10 000 h, calculate for each test piece the specific ring stiffness under wet conditions, for position 1, using Equation (9):

$$S_{x,\,1,\,\text{relax, wet}} = \frac{f \times F_{x,\,1,\,\text{wet}}}{L \times y_1} \qquad (9)$$

where

$S_{x,\,1,\,\text{relax, wet}}$ is the specific ring relaxation stiffness, after x years, in newtons per square metre, for position 1 under wet conditions;

f is the deflection coefficient, which has the value given by Equation (7):

$$f = \left[1\,860 + \left(2\,500 \times y_1 / d_\text{m}\right)\right] \times 10^{-5} \qquad (7)$$

$y_{x,\,1,\,\text{wet}}$ is the deflection, in metres, produced by the force at position 1;

L is the mean length of the test piece, in metres;

F is the value of the force, in newtons, after x years, at position 1 under wet conditions, determined in accordance with 10.6.

For each test piece, analyse the stiffness versus time data in accordance with method B of ISO 10928:1997.

11.2 Calculation of the long-term specific ring relaxation stiffness under wet conditions for position 1

Using the results of the analysis in 11.1, calculate and report the long-term specific ring relaxation stiffness under wet conditions for position 1, $S_{x,\,1,\,\text{relax, wet}}$, for x years (see 3.6) as specified by the referring standard.

11.3 Calculation of the wet relaxation factor

For each test piece, calculate the wet relaxation factor, $\alpha_{x,\,1,\,\text{relax, wet}}$, using Equation (6):

$$\alpha_{x,\,\text{relax, wet}} = \frac{S_{x,\,1,\,\text{relax, wet}}}{S_{0,\,1}} \qquad (6)$$

where

$S_{x,\,1,\,\text{relax, wet}}$ is the long-term specific ring relaxation stiffness, in newtons per square metre, after x years, at position 1 under wet conditions (see 11.2);

$S_{0,\,1}$ is the initial specific ring stiffness, in newtons per square metre, at position 1.