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# Thermoplastics pipes — Determination of creep ratio

*Tubes en matières thermoplastiques — Détermination du taux de fluage*

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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 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

This third edition cancels and replaces the second edition (ISO 9967:2007), which has been technically revised.

# Introduction

Experience shows that when a pipe is installed in the soil in accordance with an appropriate code of practice an increase in deflection may be observed. Depending on the soil and installation conditions this period will vary but normally not exceed two years.

Therefore, the two-year creep ratio as determined in accordance with this International Standard is intended for use when long-term static calculations are carried out.

The theory of creep in thermoplastics materials is briefly explained in Annex A.

For experiments, the test can be carried out based on other ages of the test pieces, other test temperatures and/or other test durations.

# Thermoplastics pipes — Determination of creep ratio

## 1 Scope

This International Standard specifies a method for determining the creep ratio of thermoplastics pipes having a circular cross-section.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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*

## 3 Symbols

| | | Unit |
|---|---|---|
| $d_n$ | nominal diameter of pipe | mm |
| $d_i$ | inside diameter of test piece of pipe | mm |
| $F$ | loading force | kN |
| $F_0$ | pre-load force | N |
| $p$ | pitch | mm |
| $L$ | length of test piece | mm |
| $y_0$ | measured initial deflection | mm |
| $Y_t$ | calculated deflection at time t | mm |
| $Y_2$ | extrapolated two-year deflection | mm |
| $\delta$ | vertical deflection used to determine the loading force | mm |
| $B$ | theoretical deflection, at $t = 1$ h | mm |
| $M$ | gradient coefficient | |
| $N$ | number of points on the deflection curve used for the linear regression | |
| $R$ | correlation coefficient | |
| $t$ | time | h |
| $x$ | log($t$) | |
| $y$ | measured total deflection | mm |
| $\gamma$ | creep ratio | |

| | | |
|---|---|---|
| $S$ | stiffness | kN/m[2] |
| $E$ | modulus of elasticity of the material | kN/m[2] |
| $I$ | moment of inertia | m[3] |
| $D$ | mean diameter of the test ring | m |

## 4 Principle

A cut length of pipe is placed between two parallel flat horizontal plates and a constant compressive force is applied for 1 008 h (42 days).

The deflection of the pipe is recorded at specified intervals so as to prepare a plot of pipe deflection against time. The linearity of the data are analysed and the creep ratio is calculated as the ratio between the two years' extrapolated deflection value and the measured 6 min (0,1 h) deflection.

NOTE It is assumed that the test temperature, as appropriate (see 8.1), is set by the referring standard.

## 5 Apparatus

**5.1 Compressive loading machine**, capable of applying via plates (5.2) and maintaining to with a precision of ± 1 % both the applicable pre-load force, $F_0$ (see 8.4), and the necessary loading force, $F$ (see 8.5), on the pipe.

The force may be applied either directly or indirectly, e.g. by use of a lever arm arrangement.

**5.2 Two plates**, through which the compressive force can be applied to the test piece. The plates shall be flat, smooth and clean and shall not deform during the test to an extent that would affect the results.

The length of each plate shall be at least equal to the length of the test piece. The width of each plate shall be not less than the maximum width of the contact surface with the test piece while under load plus 25 mm.

**5.3 Dimensional measuring devices**, capable of determining:

— individual values for the length of a test piece (see 6.2) to with an accuracy of ± 1 mm;

— the inside diameter of a test piece to with an accuracy of ± 0,1 mm or ± 0,2 % $d_i$, whichever is the greater;

— the change in inside diameter of a test piece in the direction of loading with an accuracy of 0,1 mm or 0,1 % of the deflection, whichever is the greater.

The change in inside diameter may be measured inside the pipe or be determined from the movement of the upper plate. In case of dispute the inside diameter shall be used as reference.

An example of a device for measuring the inside diameter of corrugated pipes is shown in Figure 1.

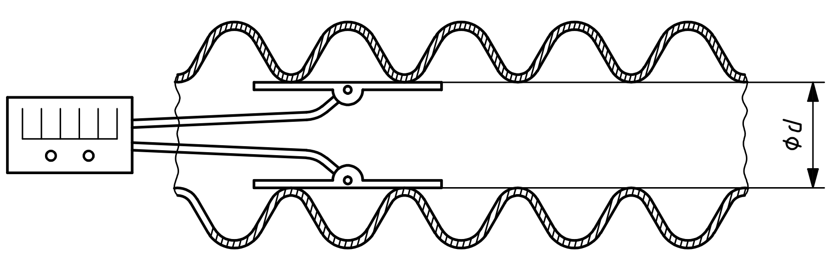



**Figure 1 — Example of device for measuring the inside diameter of a corrugated pipe**

**5.4 Timer,** capable of determining the first 6 min with an accuracy to within 1 s and the remaining times to within 0,1 % (see 8.5 and 8.6).

# 6 Test pieces

## 6.1 Marking and number of test pieces

The pipe of which the creep ratio is to be determined shall be marked on its outside with a line along one generatrix for its full length. Three test pieces, A, B and C respectively, shall be taken from this marked pipe such that the ends of the test pieces are perpendicular to the pipe axis and their lengths conform to 6.2.

## 6.2 Length of test pieces

**6.2.1** The length of each test piece shall be determined by calculating the arithmetic average of three to six measurements of length equally spaced around the perimeter of the pipe as given in Table 1. The length of each test piece shall conform to 6.2.2, 6.2.3, 6.2.4 or 6.2.5, as applicable.

Each of the three to six length measurements shall be determined to within 1 mm.

For each individual test piece, the smallest of the three to six measurements shall not be less than 0,9 times the largest length measurement.

**Table 1 — Number of length measurements**

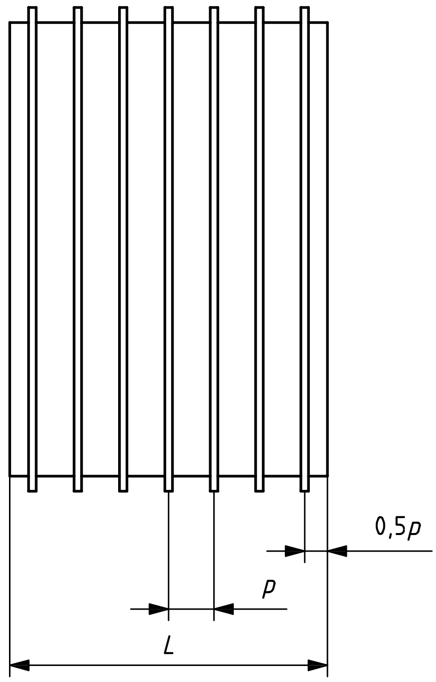
| **Nominal diameter, $d_n$, of pipe**<br>mm | **Number of length measurements** |
|---|---|
| $d_n \leq 200$ | 3 |
| $200 < d_n < 500$ | 4 |
| $d_n \geq 500$ | 6 |

**6.2.2** For pipes that have a nominal diameter, $d_n$, less than or equal to 1 500 mm, the average length of the test pieces shall be (300 ± 10) mm.

**6.2.3** For pipes that have a nominal diameter, $d_n$, larger than 1 500 mm, the average length of the test pieces in millimetres shall be at least 0,2 $d_n$.

**6.2.4** Structured wall pipes with perpendicular ribs, corrugations or other regular structures shall be cut such that each test piece contains a whole number of ribs, corrugations or other structures. The cuts shall be made at the mid-point between the ribs, corrugations or other structures.

The length of the test pieces shall be the minimum whole number of ribs, corrugations or other structures resulting in a length of 290 mm or greater, or 0,2 $d_n$ or greater for pipes larger than 1 500 mm. See Figure 2.




**Key**

*p* pitch

*L* length of test piece

**Figure 2 — Test piece cut out of a perpendicularly ribbed pipe**

**6.2.5** Structured-wall pipes with helical ribs, corrugations or other regular structures shall be cut square such that the length of the test pieces is equal to the inside diameter ± 20 mm but not less than 290 mm or greater than 1 000 mm.

## 6.3 Inside diameter of test piece(s)

The inside diameters, $d_{iA}$, $d_{iB}$ and $d_{iC}$, of the respective test pieces, A, B and C (see 6.1), shall be determined either as

a) the arithmetic average of four or more measurements in accordance with ISO 3126 of one cross-section at mid-length, where each measurement shall be determined to with an accuracy of ± 0,1 mm or ± 0,2 % $d_i$, whichever is the greater, or

b) measured at mid-length of cross-section by means of a π-tape in accordance with ISO 3126.

The calculated or measured average inside diameter for each test piece, A, B and C, shall be recorded as $d_{iA}$, $d_{iB}$ and $d_{iC}$ respectively.

The average value, $d_i$, of these three calculated values shall be calculated using Formula (1):

$$d_i = \frac{d_{iA} + d_{iB} + d_{iC}}{3} \quad (1)$$

## 6.4 Age of test pieces

At the start of testing in accordance with Clause 8, the age of the test pieces shall be (21 ± 2) days.

## 7 Conditioning

The test pieces shall be conditioned in air at the test temperature (see 8.1) for at least 24 h immediately prior to testing in accordance with Clause 8.

## 8 Test procedure

**8.1** Unless otherwise specified in the referring standard, carry out the following procedures at (23 ± 2) °C, or, in countries where 27 °C is used as standard laboratory temperature, at (27 ± 2) °C.

In case of dispute, (23 ± 2) °C shall be used.

**8.2** If it can be determined in which position the test piece has the lowest ring stiffness, place the first test piece, A, in this position in its loading device.

Otherwise, place the first test piece in such a way that the marking line is in contact with the upper parallel plate.

Rotate the two others, B and C, 120° and 240° respectively, in relation to the position of the first test piece when placing them in their loading devices.

**8.3** For each test piece, attach the deflection gauge and check the angular position of the test piece, related to the upper parallel plate.

**8.4** Lower the loading plate until it touches the upper part of the test piece.

Apply one or the other of the following pre-load forces, $F_0$, as applicable, rounded to the next higher integer if calculated from Formula (2) [see Item b)] and, if applicable, taking the mass of the loading plate into account:

a) for pipes with $d_i$ less than or equal to 100 mm, $F_0$ shall be 7,5 N.

b) for pipes with $d_i$ larger than 100 mm, $F_0$ shall be calculated using Formula (2) and rounding the result where necessary to the next higher integer:

$$F_0 = 250 \times 10^{-6} d_i \times L_1 \quad (2)$$

where

$F_0$ is the calculated pre-load, in newtons;

$d_i$ is the mean actual inside diameter of the pipe test piece, in millimetres;

$L_1$ is the calculated average length of the test piece, in millimetres.

The pre-load force effectively applied shall be between 95 % and 105 % of the calculated pre-load force.

**8.5** Within 5 min of having applied the pre-load force, $F_0$, adjust the deflection gauge to zero and commence applying to the test piece an increasing compressive force such that after between 20 s and 30 s a loading force, $F$, is achieved. This force, $F$, shall be chosen such that after 360 s (6 min) the test piece shows a deflection ratio of (1,5 ± 0,2) %, i.e.:

$$\frac{\delta}{d_i} = 0{,}015 \pm 0{,}002 \quad (3)$$

At the moment that the full force $F$ is achieved, start the timer.

**8.6** Determine the initial deflection, $y_0$, 6 min after the application of the full load. Then determine the deflection after application of the full load after 1 h, 4 h, 24 h, 168 h, 336 h, 504 h, 600 h, 696 h, 840 h and 1 008 h.

If the value of $y_0$ is outside the limits specified in 8.5, interrupt the test, recondition the test piece for at least one hour and restart the test at 8.3.

Where it is not possible to read the deflection gauges at the appropriate times between 500 h and 1 008 h, it is permitted to deviate by ± 48 h, providing the actual time for measurement is used for plotting in accordance with Clause 9.

EXAMPLE Instead of reading at 840 h, the deflection is read after 862 h. In this case the value of 862 h is used in the regression analysis.

NOTE When the creep test is started on a Monday or Thursday, interference with weekends does not occur.

## 9 Determination of the creep ratio

**9.1** For each of the three test pieces, plot the deflection in metres against the logarithm of time in hours in a single logarithmic coordinate system (see Figure 3) and determine by linear regression the equation of the straight line:

$$Y_t = B + M \log t \tag{4}$$

through all 11 points and through the last 10 points, through the last nine points, ..., and through the last five points (see Table 2), where the constants $B$ and $M$ and the correlation coefficient, $R$, are determined using Formulae (5) to (7), i.e. the method of least squares:

$$M = \frac{N\sum x_i y_i - \sum y_i \sum x_i}{N\sum x_i^2 - \left(\sum x_i\right)^2} \tag{5}$$

$$B = \frac{\sum y_i - M\sum x_i}{N} \tag{6}$$

$$R = \left[\frac{M\left(N\sum x_i y_i - \sum x_i \sum y_i\right)}{N\sum y_i^2 - \left(\sum y_i\right)^2}\right]^{1/2} \tag{7}$$

where

$B$ is the theoretical deflection, in millimetres, at $t$ = 1 h;

$M$ is the gradient coefficient;

$N$ is the number of points on the deflection curve used for the linear regression;

$R$ is the correlation coefficient (if $R$ has a value between 0,99 and 1,00, it is assumed that the plotted points lie on a straight line);

$Y_2$ is the extrapolated deflection, in millimetres, after two years (17 520 h);

$t_i$ is the time for point $i$;

$x_i$ = $\log(t_i)$;

$y_i$ is the measured total deflection at time $t_i$.

For the seven equations of $Y_t = B + M \log t$, obtained for a given test piece, calculate the extrapolated two-year deflection $Y_2$ ($t$ = 2 years = 17 520 h) (see Table 2).

Choose as the value for the two years' deflection, $Y_2$ (for calculation of the creep ratio of the test piece), the highest calculated $Y_2$ that is accompanied by a correlation coefficient, $R$, of 0,999 or the highest value between 0,990 and 0,999.

If the highest value is less than 0,990, see 9.3.

Having determined $Y_2$, calculate the creep ratio for each of the three test pieces using Formulae (8) to (10):

$$\gamma_A = \frac{Y_{2A}\left(0{,}018\,6 + 0{,}025\,\dfrac{y_{0A}}{d_i}\right)}{y_{0A}\left(0{,}018\,6 + 0{,}025\,\dfrac{Y_{2A}}{d_i}\right)} \tag{8}$$

$$\gamma_B = \frac{Y_{2B}\left(0{,}018\,6 + 0{,}025\,\dfrac{y_{0B}}{d_i}\right)}{y_{0B}\left(0{,}018\,6 + 0{,}025\,\dfrac{Y_{2B}}{d_i}\right)} \tag{9}$$

$$\gamma_C = \frac{Y_{2C}\left(0{,}018\,6 + 0{,}025\,\dfrac{y_{0C}}{d_i}\right)}{y_{0C}\left(0{,}018\,6 + 0{,}025\,\dfrac{Y_{2C}}{d_i}\right)} \tag{10}$$

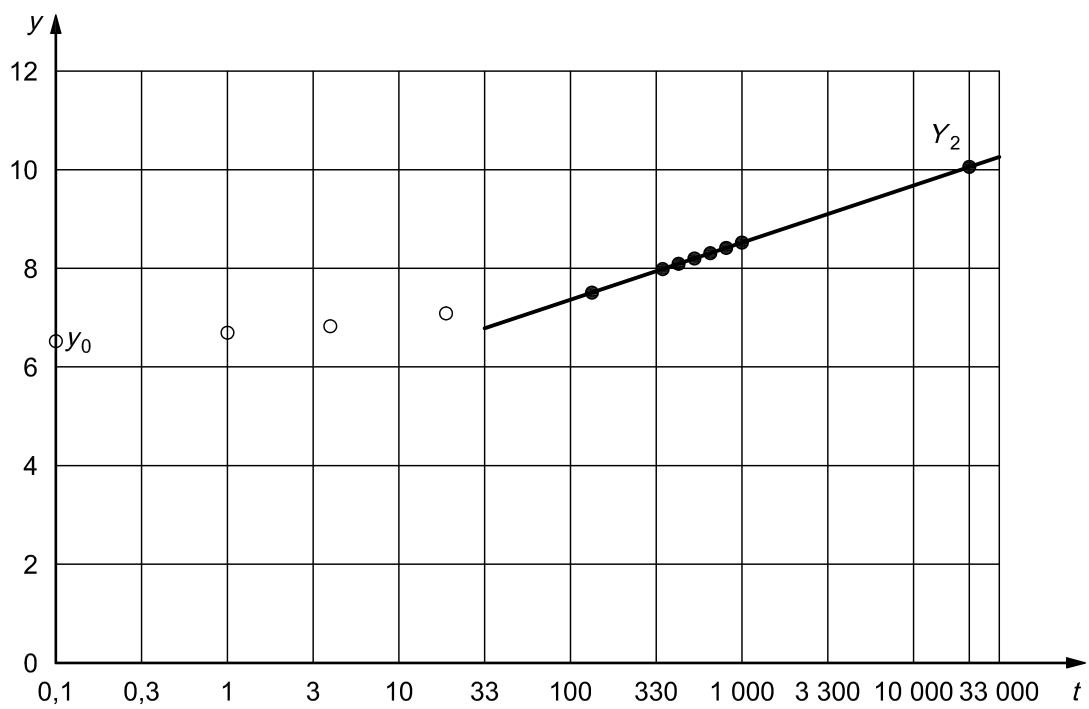
Calculate and record the creep ratio of the pipe as the arithmetic average of the three calculated values using Formula (11):

$$\gamma = \frac{\gamma_A + \gamma_B + \gamma_C}{3} \tag{11}$$

EXAMPLE Calculation of creep: an example deflection/time data set for one test piece is given in Table 2, together with the consequent values for $M$, $B$, $R$ and $Y_2$ for different ranges of data points as given in column four, which indicates those points that have been included in the regression analysis. The resulting plot is given in Figure 3 where, in accordance with this subclause, $Y_2$ is based on the set of not less than five points for which $R$ has the highest value above 0,990.

**Table 2 — Data corresponding to Figure 3**

| Point no. | Time $t$ h | $Y_t$ mm | Range of points | $M$ | $B$ | $R$ | $Y_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 0,1 | 6,53 | 1 to 11 | 0,505 | 6,684 | 0,951 | 8,825 |
| 2 | 1 | 6,65 | 2 to 11 | 0,611 | 6,425 | 0,967 | 9,017 |
| 3 | 4 | 6,78 | 3 to 11 | 0,709 | 6,172 | 0,972 | 9,179 |
| 4 | 24 | 7,02 | 4 to 11 | 0,885 | 5,696 | 0,982 | 9,436 |
| 5 | 168 | 7,53 | 5 to 11 | 1,195 | 4,830 | 0,997 | 9,914 |
| 6 | 336 | 7,85 | 6 to 11 | 1,299 | 4,517 | 0,997 | 10,060 |
| 7 | 504 | 8,05 | 7 to 11 | 1,410 | 4,174 | 0,998 | 10,211 |
| 8 | 600 | 8,13 | | | | | |
| 9 | 696 | 8,23 | | | | | |
| 10 | 840 | 8,38 | | | | | |
| 11 | 1008 | 8,46 | | | | | |




**Key**

$t$ time, h

$y$ deflection, mm

$y_0$ initial deflection

$Y_2$ two years' extrapolated deflection

**Figure 3 — Deflection/time plot for one test piece**

**9.2** In some calculation methods, 50 year values are still required. The 50 year deflection value, $Y_{50}$, can be calculated by using the procedure specified in 9.1, but inserting 50 years (438 000 h) in the equation instead of 2 years.

**9.3** If the use of even the last five points does not lead to a correlation coefficient higher than 0,990 in the regression analysis for any of the three test pieces, continue the test on all three test pieces by measuring the deflection at 1 200 h, 1 400 h, 1 680 h, 2 000 h, 2 400 h, 2 818 h, 3 400 h or 4 000 h, in each case ± 48 h, or until the correlation coefficient exceeds 0,990 using the last five measurements, whichever occurs first.

## 10 Test report

The test report shall include the following information:

a) reference to this International Standard and to the referring standard, if any;

b) identification of the thermoplastics pipe, including

   1) manufacturer,

   2) type of pipe,

   3) type of material,

   4) dimensions and classes,

   5) production date,

   6) lengths of test pieces, and

   7) mass per metre length of the pipe;

c) test temperature;

d) pre-load force applied;

e) force/deflection graph for each test piece;

f) where appropriate, force and deflection at which any of the events specified in 8.2 occurred;

g) deflection and force at the maximum point, if a maximum occurred;

h) equations $Y_t = B + M \log t$ used for extrapolation to the two-year deflection point for the three test pieces;

i) correlation coefficient in each case;

j) points used for the linear regression analysis;

k) calculated values of $\gamma_A$, $\gamma_B$ and $\gamma_C$;

l) calculated value of the creep ratio $\gamma$, rounded to two significant figures;

m) any factors that could have affected the results, such as any incidents or any operating details not specified in this standard;

n) date of start of the test.

# Annex A
(informative)

# Creep in thermoplastics material

**A.1** Plastics pipes subjected to a constant load will be deflected when installed in the soil with an initial deflection that can be estimated using the stiffness of the pipe. This stiffness, expressed as *S*, can be determined, in kilonewtons per square metre, by using the test method according to ISO 9969[1] and Formula (A.1):

$$S = \left(0{,}018\ 6 + 0{,}025\,\frac{y}{d_\mathrm{i}}\right)\frac{F}{Ly} \qquad \text{(A.1)}$$

where

$F$ is the force needed to obtain the (required) deflection, in kilonewtons;

$L$ is the length of the test ring, in metres;

$y$ is the deflection of the ring, in metres.

The stiffness of a pipe ring of constant cross-section can also be calculated using material properties and geometrical factors in Formula (A.2):

$$S = \frac{EI}{D^3} \qquad \text{(A.2)}$$

where

$E$ is the modulus of elasticity of the material;

$I$ is the moment of inertia;

$D$ is the mean diameter of the test ring.

Plastics pipes subjected to a constant load in a laboratory test will, in addition to their initial deflection, show an increasing deflection in time. This is caused by creep of the material.

**A.2** Plastics materials on the molecular scale can be considered to be built up from a great number of long chains. When a force is applied to the material, the chains themselves deform immediately, giving the initial deflection.

When the material is subjected to a constant load, the chains under the influence of that force will move relative to each other, causing creep: a continuously increasing deformation. The structure of the chain does not change; therefore, the material still shows the same immediate reaction when, during the application of a constant load, this load is increased.

**A.3** For design purposes it is necessary to know the deflection of the pipe directly after installation and in the long term.

An estimate of the initial deflection can be obtained using the stiffness, *S*, of the pipe.

NOTE In practice the nominal stiffness, $S_\mathrm{n}$, can be used.

A rough indication of the long-term (theoretical) deflection under constant load was formerly calculated using the specific tangential end stiffness (STES) of the pipe, taking into account the behaviour of the materials surrounding the pipe. The STES was the long-term stiffness, obtained by substituting in place of the modulus of elasticity of the material [Formula (A.2)] the creep modulus [apparent modulus], i.e. the initial modulus of the material divided by the creep ratio, $\gamma$, i.e.:

$$[\mathrm{STES}] = \frac{S}{\gamma} \tag{A.3}$$

This approach can give rise to the interpretation that the modulus of elasticity will reduce in time, causing confusion and a negative opinion on the suitability of plastics for buried pipes.

In order to avoid confusion, the preferred method for calculation is to use the creep ratio, $\gamma$, calculated using Formula (A.4):

$$\gamma = \frac{Y_2\left(0{,}018\,6 + 0{,}025\,\dfrac{y_0}{d_\mathrm{i}}\right)}{y_0\left(0{,}018\,6 + 0{,}025\,\dfrac{Y_2}{d_\mathrm{i}}\right)} \tag{A.4}$$

# Bibliography

[1] ISO 9969, *Thermoplastics pipes — Determination of ring stiffness*

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