FINAL DRAFT International Standard

ISO/FDIS 10928

ISO/TC **138**/SC **6**

Secretariat: **ASI**

Voting begins on:
2023-12-26

Voting terminates on:
2024-02-20

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

Systèmes de canalisations en matières plastiques — Tubes et raccords plastiques thermodurcissables renforcés de verre (PRV) — Méthodes pour une analyse de régression et leurs utilisations

RECIPIENTS OF THIS DRAFT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

Reference number
ISO/FDIS 10928:2023(en)

Contents

Page

Foreword .... **iv**

Introduction .... **v**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **1**

4 Principle **1**

5 Procedures for determining the linear relationships — Methods A and B **2**

5.1 Procedures common to methods A and B 2

5.2 Method A — Covariance method 2

5.2.1 General 2

5.2.2 Suitability of data 3

5.2.3 Functional relationships 3

5.2.4 Calculation of variances 4

5.2.5 Check for the suitability of data for extrapolation 4

5.2.6 Validation of statistical procedures by an example calculation 5

5.3 Method B — Regression with time as the independent variable 8

5.3.1 General 8

5.3.2 Suitability of data 9

5.3.3 Functional relationships 9

5.3.4 Check for the suitability of data for extrapolation 9

5.3.5 Validation of statistical procedures by an example calculation 9

6 Application of methods to product design and testing **11**

6.1 General 11

6.2 Product design 11

6.3 Comparison to a specified value 11

6.4 Declaration of a long-term value 11

Annex A (informative) **Second-order polynomial relationships** **12**

Annex B (normative) **Calculation of lower confidence and prediction limits for method A** **16**

Bibliography **19**

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 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 fourth edition cancels and replaces the third edition (ISO 10928:2016), which has been technically revised.

The main changes are as follows:

— Annex B, “Non-linear relationships”, has been removed due to its complexity and highly specialized and limited application;

— Formula (B.3) [Formula (C.3) in ISO 10928:2016] has been corrected to include a factor 2 before Bx_{L}.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document describes the procedures intended for analysing the regression of test data, usually with respect to time, and the use of the results in the design and assessment of conformity with performance requirements. Its applicability is limited to use with data obtained from tests carried out on samples. Referring standards require estimates to be made of the long-term properties of the pipe for such parameters as circumferential tensile strength, long-term ring deflection, strain corrosion and creep or relaxation stiffness.

A range of statistical techniques that can be used to analyse the test data produced by destructive tests were investigated in the preparation of this document. Many of these simple techniques require the logarithms of the data to:

a) be normally distributed;

b) produce a regression line having a negative slope; and

c) have a sufficiently high regression correlation (see Table 1).

Analysis of data from several tests showed that in the destructive test context, while conditions b) and c) can be satisfied, there is often a skew to the distribution and hence condition a) is not satisfied. Further investigation into techniques that can handle skewed distributions resulted in the adoption of the covariance method (method A, see 5.2) for the analysis of such data within this document.

The results from non-destructive tests, such as long-term creep or relaxation stiffness, often satisfy all three conditions. Therefore, a simpler procedure, using time as the independent variable (method B, see 5.3), can also be used in accordance with this document.

These two analysis procedures (method A and method B) are limited to analysis methods specified in ISO product standards or test methods. Other analysis procedures can be useful for the extrapolation and prediction of long-term behaviour of some properties of glass-reinforced thermosetting plastics (GRP) piping products. For example, a second-order polynomial analysis is sometimes useful in the extrapolation of creep and relaxation data. This is particularly the case for analysing shorter term data, where the shape of the creep or relaxation curve can deviate considerably from linear. A second-order polynomial analysis is included in Annex A.

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

1 Scope

This document specifies procedures suitable for the analysis of data which, when converted into logarithms of the values, have either a normal or a skewed distribution. It is intended for use with test methods and referring standards for glass-reinforced thermosetting plastics (GRP) pipes or fittings for the analysis of properties as a function of time. However, it can also be used for the analysis of other data.

Two methods are specified, which are used depending on the nature of the data. Extrapolation using these techniques typically extends a trend from data gathered over a period of approximately 10 000 h to a prediction of the property at 50 years, which is the typical maximum extrapolation time.

This document only addresses the analysis of data. The test procedures for collecting the data, the number of samples required and the time period over which data are collected are covered by the referring standards and/or test methods. Clause 6 discusses how the data analysis methods are applied to product testing and design.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 Principle

Data are analysed for regression using methods based on least squares analysis which can accommodate the incidence of a skew or a normal distribution or both. The two methods of analysis used are the following:

— method A: covariance using a first-order relationship;

— method B: least squares, with time as the independent variable using a first-order relationship.

The methods include statistical tests for the correlation of the data and the suitability for extrapolation.

5 Procedures for determining the linear relationships — Methods A and B

5.1 Procedures common to methods A and B

Use method A (see 5.2) or method B (see 5.3) to fit a straight line of the form given in Formula (1):

$$y = a + b \times x \tag{1}$$

where

y is the logarithm, lg, of the property being investigated;

a is the intercept on the y-axis;

b is the slope;

x is the logarithm, lg, of the time, in hours.

5.2 Method A — Covariance method

5.2.1 General

For method A, calculate the following variables in accordance with 5.2.2 to 5.2.5, using Formulae (2), (3) and (4):

$$Q_y = \frac{\sum (y_i - Y)^2}{n} \tag{2}$$

$$Q_x = \frac{\sum (x_i - X)^2}{n} \tag{3}$$

$$Q_{xy} = \frac{\sum [(x_i - X) \times (y_i - Y)]}{n} \tag{4}$$

where

Q_y is the sum of the squared residuals parallel to the y-axis, divided by n;

Q_x is the sum of the squared residuals parallel to the x-axis, divided by n;

Q_{xy} is the sum of the squared residuals perpendicular to the line, divided by n;

Y is the arithmetic mean of the y data, i.e. given as Formula (5):

$$Y = \frac{\sum y_i}{n} \tag{5}$$

X is the arithmetic mean of the x data, i.e. given as Formula (6):

$$X = \frac{\sum x_i}{n} \tag{6}$$

x_i, y_i are individual values;

n is the total number of results (pairs of readings for x_i, y_i).

NOTE If the value of Q_{xy} is greater than zero, the slope of the line is positive and if the value of Q_{xy} is less than zero, then the slope is negative.

5.2.2 Suitability of data

Calculate the linear coefficient of correlation, *r*, using Formulae (7) and (8):

$$r^2 = \frac{Q_{xy}^2}{Q_x \times Q_y} \tag{7}$$

$$r = \left| \left(r^2 \right)^{0,5} \right| \tag{8}$$

Table 1 gives the minimum acceptable values of the correlation coefficient, *r*, as a function of the number of variables, *n*, and Student´s *t*-distribution t_ν, where t_ν is based on a two-sided 0,01 level of significance.

Table 1 — Minimum values of the correlation coefficient, *r*, for acceptable data from *n* pairs of data

Number of variables *n*	Degrees of freedom *n* − 2	Student's *t* -distribution t_ν (0,01)	Minimum *r*
13	11	3,106	0,683 5
14	12	3,055	0,661 4
15	13	3,012	0,641 1
16	14	2,977	0,622 6
17	15	2,947	0,605 5
18	16	2,921	0,589 7
19	17	2,898	0,575 1
20	18	2,878	0,561 4
21	19	2,861	0,548 7
22	20	2,845	0,536 8
23	21	2,831	0,525 6
24	22	2,819	0,515 1
25	23	2,807	0,505 2
26	24	2,797	0,495 8
27	25	2,787	0,486 9
32	30	2,750	0,448 7
37	35	2,724	0,418 2
42	40	2,704	0,393 2
47	45	2,690	0,372 1
52	50	2,678	0,354 2
62	60	2,660	0,324 8
72	70	2,648	0,301 7
82	80	2,639	0,283 0
92	90	2,632	0,267 3
102	100	2,626	0,254 0

5.2.3 Functional relationships

Find *a* and *b* for the functional relationship line using Formula (1).

First, set the gamma function Γ as given in Formula (9):

$$\Gamma = \frac{Q_y}{Q_x} \tag{9}$$

then calculate *a* and *b* using Formulae (10) and (11):

$$b = -(\Gamma)^{0,5} \tag{10}$$

$$a = Y - b \times X \tag{11}$$

5.2.4 Calculation of variances

If t_u is the applicable time to failure, then set x_u, the logarithm of t_u, as given in Formula (12):

$$x_u = \lg t_u \tag{12}$$

Using Formulae (13), (14) and (15) respectively, calculate for i = 1 to n, the following sequence of statistics:

— the best fit x_i' for true x_i;

— the best fit y_i' for true y_i;

— the error variance, σ_δ^2, for x.

$$x_i' = \frac{\Gamma \times x_i + b \times (y_i - a)}{2 \times \Gamma} \tag{13}$$

$$y_i' = a + b \times x_i' \tag{14}$$

$$\sigma_\delta^2 = \frac{\left[\sum (y_i - y_i')^2 + \Gamma \times \sum (x_i - x_i')^2\right]}{(n-2) \times \Gamma} \tag{15}$$

Calculate quantities E and D using Formulae (16) and (17):

$$E = \frac{b \times \sigma_\delta^2}{2 \times Q_{xy}} \tag{16}$$

$$D = \frac{2 \times \Gamma \times b \times \sigma_\delta^2}{n \times Q_{xy}} \tag{17}$$

Calculate the variance, C, of the slope b, using Formula (18):

$$C = D \times (1 + E) \tag{18}$$

5.2.5 Check for the suitability of data for extrapolation

If it is intended to extrapolate the line, calculate the parameter T using Formula (19):

$$T = \frac{b}{(\text{var } b)^{0,5}} = \frac{b}{C^{0,5}} \tag{19}$$

If the absolute value, $|T|$ (i.e. ignoring signs), of T is equal to or greater than the applicable value for Student's t-distribution, t_v, shown in Table 2 for (n − 2) degrees of freedom, then consider the data suitable for extrapolation.

Calculation of confidence limits is not required by the test methods or referring standards. However, the calculation of the lower confidence limit (LCL), and lower prediction limit (LPL) shall be in accordance with Annex B.