

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

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- British Plastics Federation
- British Plumbing Fittings Manufacturers' Association
- British Valve and Actuator Manufacturers' Association
- Department of the Environment (British Board of Agrément)
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- Department of Transport
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- Pipeline Industries Guild
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- Water Services Association of England and Wales

This British Standard, having been prepared under the direction of the Sector Board for Materials and Chemicals, was published under the authority of the Standards Board and comes into effect on 15 November 1995

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The following BSI references relate to the work on this standard:
Committee reference PRI/61
Draft for comment 92/41338 DC

ISBN 0 580 24136 X

Amendments issued since publication

Amd. No.	Date	Comments

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National foreword

This British Standard has been prepared by Technical Committee PRI/61, and is the English language version of EN 705:1994 *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Methods for regression analyses and their use*, published by the European Committee for Standardization (CEN).

It is incorporated into BS 2782 *Methods of testing plastics — Part 12. Reinforced plastics pipes, fittings and valves*, as Methods 1220A to C:1995 as follows.

Method 1220A corresponds to method A (Covariance method) of EN 705:1994.

Method 1220B corresponds to method B (Regression with time as the independent variable) of EN 705:1994.

Method 1220C corresponds to method C (Second order polynomial relationships) of EN 705:1994.

These methods are incorporated into BS 2782 for association with related test methods for plastics materials and plastics piping components.

This test method has been prepared for reference by other standards under preparation by CEN for specification of reinforced plastics piping systems and components. It has been implemented as a national standard to enable experience of the method to be gained and for use for other fresh applications.

It is also for use for the revision or amendment of other national standards as practicable, but it should not be presumed to apply to any existing standard or specification which contains or makes reference to a different method until that standard/specification has been amended or revised to make reference to this method and adjust any requirements as appropriate.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 31 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

UDC 621.643.2-036.067.5:621.643.06:620.1:519.2

Descriptors: Pipelines, plastic tubes, pipe fittings, thermosetting resins, reinforced plastics, glass, data, statistical analysis, computation, design inspection

English version

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

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

Kunststoff-Rohrleitungssysteme — Rohre und Formstücke aus glasfaserverstärkten duroplastischen Kunststoffen (GFK) — Verfahren zur Regressionsanalyse und deren Anwendung

This European Standard was approved by CEN on 1994-04-11. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Foreword

This standard was prepared by CEN/TC 155, Plastics piping systems and ducting systems.

This standard is based on document N 197 *Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Standard extrapolation procedures and their use*, prepared by working group 1 of Subcommittee 6 of Technical Committee 138 of the International Organization for Standardization (ISO). It is a modification of ISO/TC 138/SC6/WG 1 N 197 for reasons of possible applicability to other test conditions and alignment with texts of other standards on test methods.

The modifications are:

- examples have been introduced to enable validation of alternative calculation facilities;
- material-dependent requirements are not given;
- editorial changes have been introduced.

The material-dependent test parameters and/or performance requirements are incorporated in the referring standard.

Annex A, which is informative, describes procedures for solving the given set of equations (see **3.2.3**) on a mathematical basis using the example shown in **3.2.6**.

No existing European Standard is superseded by this standard.

This standard is one of a series of standards on test methods which support System Standards for plastics piping systems and ducting systems.

This standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 1994, and conflicting national standards shall be withdrawn at the latest by October 1994.

In accordance with the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

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Introduction

This standard has been prepared to describe the procedures intended for analysing the regression of test data, usually with respect to time, and the use of the results in design and assessment of conformity with performance requirements. Its applicability has been limited to use with data obtained from tests carried out on samples. The referring standards require estimates to be made of the long-term properties of the pipe for such parameters as circumferential tensile strength, deflection and creep.

The committee investigated a range of statistical techniques that could be used to analyse the test data produced by tests that were destructive. Many of these simple techniques required 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).

Whilst the last two conditions can be satisfied, analysis has shown that there is a skew to the distribution and hence this primary condition is not satisfied. Further investigation into techniques that can handle skewed distributions resulted in the adoption of the covariance method for analysis of such data for this standard.

The results from non-destructive tests, such as creep or changes in deflection with time, often satisfy these three conditions and hence simpler procedures, using time as the independent variable, can also be used in accordance with this standard.

1 Scope

This standard 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 the test methods and referring standards for glass-reinforced plastics pipes or fittings for the analysis of properties as a function of, usually, time. However it can be used for the analysis of any other data.

For use depending upon the nature of the data, three methods are specified. The extrapolation using these techniques typically extends the trend from data gathered over a period of approximately 10 000 h, to a prediction of the property at 50 years.

2 Principle

Data are analysed for regression using methods based on least squares analysis which can accommodate the incidence of a skew and/or a normal distribution and the applicability of a first order or a second order polynomial relationship.

The three methods of analysis used comprise 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;
- method C: least squares with time as the independent variable using a second order relationship.

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

3 Procedures for determining the functional relationships

3.1 Linear relationships — Methods A and B

3.1.1 Procedures common to methods A and B

Use method A (see 3.1.2) or method B (see 3.1.3) to fit a straight line of the form

$$y = a + bx \quad (1)$$

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.

3.1.2 Method A — Covariance method

3.1.2.1 General

For method A calculate the following variables as necessary in accordance with 3.1.2.2 to 3.1.2.5:

$$Q_y = \frac{\Sigma(y_i - Y)^2}{n} \quad (2)$$

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

$$Q_{xy} = \frac{\Sigma\{(x_i - X)(y_i - Y)\}}{n} \quad (4)$$

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.

$$Y = \frac{\Sigma y_i}{n};$$

X is the arithmetic mean of the x data, i.e.

$$X = \frac{\Sigma x_i}{n};$$

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.

3.1.2.2 Suitability of data

Calculate the squared, r^2 , and the linear coefficient of correlation, r , using the following equations:

$$r^2 = \frac{Q_{xy}^2}{Q_x Q_y} \quad (5)$$

$$r = |(r^2)^{0.5}| \quad (6)$$

If the value of r^2 or r is less than the applicable minimum value given in Table 1 as a function of n , consider the data unsuitable for analysis.

3.1.2.3 Functional relationships

To find a and b for the functional relationship line

$$y = a + bx \quad (1)$$

first set

$$\Gamma = \frac{Q_y}{Q_x} \quad (7)$$

then calculate a and b using the following equations:

$$b = -(\Gamma)^{0.5} \quad (8)$$

$$a = Y - bX \quad (9)$$

3.1.2.4 Calculation of variances

If t_u is the applicable time to failure, then set

$$x_u - \lg t_u \quad (10)$$

Using equations (11), (12) and (13) 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 ; and

— the error variance, σ_δ^2 for x .

$$x_i' = \frac{\Gamma x_i + b(y_i - a)}{2\Gamma} \quad (11)$$

$$y_i' = a + bx_i' \quad (12)$$

$$\sigma_\delta^2 = \frac{\{\Sigma(y_i - y_i')^2 + \Gamma \Sigma(x_i - x_i')^2\}}{(n - 2)\Gamma} \quad (13)$$

Calculate the following quantities:

$$E = \frac{b\sigma_\delta^2}{2Q_{xy}} \quad (14)$$

$$D = \frac{2\Gamma b\sigma_\delta^2}{nQ_{xy}} \quad (15)$$

Calculate the variance C of the slope b using the following equation:

$$C = D(1 + E) \quad (16)$$

Table 1 — Minimum values for the squared, r^2 , and linear coefficient of correlation, r , for acceptable data from n pairs of data

$(n - 2)$	Minimum values		$(n - 2)$	Minimum values	
	r^2	r		r^2	r
11	0,6416	0,8010	23	0,3816	0,6177
12	0,6084	0,7800	24	0,3689	0,6074
13	0,5781	0,7603	25	0,3569	0,5974
14	0,5506	0,7420	30	0,3070	0,5541
15	0,5250	0,7246	35	0,2693	0,5189
16	0,5018	0,7084	40	0,2397	0,4896
17	0,4805	0,6932	45	0,2160	0,4648
18	0,4606	0,6787	50	0,1965	0,4433
19	0,4425	0,6652	60	0,1663	0,4078
20	0,4256	0,6524	70	0,1443	0,3799
21	0,4099	0,6402	80	0,1273	0,3568
22	0,3953	0,6287	90	0,1139	0,3375
			100	0,1031	0,3211

NOTE In Table 1 and elsewhere in this standard, the equations and corresponding values for r^2 and r are given, for convenience of use in conjunction with reference data published elsewhere in terms of only r^2 or r .

3.1.2.5 Check for the suitability of data for extrapolation

If it is intended to extrapolate the line, calculate T using the following equation:

$$T = \frac{b}{(\text{variance of } b)^{0,5}} = \frac{b}{C^{0,5}} \quad (17)$$

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