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Second edition
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Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation

*Systèmes de canalisations et de gaines en matières plastiques —
Détermination de la résistance hydrostatique à long terme des matières
thermoplastiques sous forme de tubes par extrapolation*



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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9080 was prepared by Technical Committee 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 second edition cancels and replaces the first edition (ISO 9080:2003), which has been technically revised. The following changes have been made:

- all references to lifetime have been removed, as this standard only deals with the mathematics for extrapolation and the calculation of long-term strength;
- a more accurate description of the number and distribution of the observations and of the use of the extrapolation has been included;
- the observations in the example of Annex C have been modified in order to comply with the specifications of this standard and, consequently, the results of the regression calculations have been updated;
- a second set of observations has been added in Annex D in order to provide an evaluation according to the 3-parameter model (see Annex C), and according to the 4-parameter model (see Annex D);
- a second software package has been evaluated and included in Annex E.

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Introduction

0.1 General

This Standard Extrapolation Method (SEM) is meant to be used to evaluate the long-term hydrostatic strength of a material in pipe form. Product standards have specific requirements for the physical and mechanical properties of the material used for the intended application. It is emphasized that the Standard Extrapolation Method (SEM) described in this document is not intended to be used to disqualify existing procedures for arriving at design stresses or allowable pressures for pipelines made of plastics materials, or to disqualify pipelines made of materials proven by such procedures, for which experience over many years has been shown to be satisfactory.

Software packages have been developed for the SEM analysis as described in Annex A and Annex B. Windows-based programmes are commercially available (see Annex E). Use of these software packages is recommended.

0.2 Principles

The suitability of a plastics material for a pressure pipe is determined by its long-term performance under hydrostatic stress when tested in pipe form, taking into account the envisaged service conditions (e.g. temperature). For design purposes, it is conventional to express this by means of the hydrostatic (hoop) stress which a plastics pipe made of the material under consideration is expected to be able to withstand for 50 years at an ambient temperature of 20 °C using water as the internal test medium. The outside test environment can be water or air. This method is not intended to imply service life. In certain cases, it is necessary to determine the value of the hydrostatic strength at either shorter design times or higher temperatures, or on occasion both. The method given in this International Standard is designed to meet the need for both types of estimate. The result obtained will indicate the lower prediction limit (LPL), which is the lower confidence limit of the prediction of the value of the stress that can cause failure in the stated time at a stated temperature.

This International Standard provides a definitive procedure incorporating an extrapolation method using test data at different temperatures analysed by multiple linear regression analysis. The results permit the determination of material-specific design values in accordance with the procedures described in the relevant product standards.

This multiple linear regression analysis is based on the rate processes most accurately described by $\log_{10}(\text{stress})$ versus $\log_{10}(\text{time})$ models.

In order to assess the predictive value of the model used, it has been considered necessary to make use of the estimated 97,5 % lower prediction limit (LPL). The 97,5 % lower prediction limit is equivalent to the lower 97,5 % confidence limit for the predicted value. This convention is used in the mathematical calculations to be consistent with the literature. This aspect necessitates the use of statistical techniques.

The method can provide a systematic basis for the interpolation and extrapolation of stress rupture characteristics at operating conditions different from the conventional 50 years at 20 °C (see 5.1.5).

Thermoplastic materials in pipe form such as mineral filled thermoplastic polymer, fibre reinforced thermoplastics, plasticized thermoplastics, blends and alloys may have further considerations with regards to prediction of long term strength which have to be taken into account in the corresponding product standards.

It is essential that the medium used for pressurizing the pipe does not have an adverse effect on the pipe. In general, water is considered to be such a medium.

Long consideration was given to deciding which variable should be taken as the independent variable to calculate the long-term hydrostatic strength. The choice was between time and stress.

The basic question the method has to answer can be formulated in two ways, as indicated below:

- a) What is the maximum stress (or pressure) that a given material in pipe form can withstand at a given temperature for a defined time?

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b) What is the predicted time to failure for a material in pipe form at a given stress and temperature?

Both questions are relevant.

If the test data for the pipe under study does not show any scatter and if the pipe material can be described perfectly by the chosen empirical model, the regression with either time independence or stress independence will be identical. This is never the case because the circumstances of testing are never ideal nor will the material be 100 % homogeneous. The observations will therefore always show scatter. The regressions calculated using the two optional independent variables will not be identical and the difference will increase with increasing scatter.

The variable that is assumed to be most affected by the largest variability (scatter) is the time variable and it has to be considered as a dependent variable (random variable) in order to allow a correct statistical treatment of the data set in accordance with this method. However, for practical reasons, the industry prefers to present stress as a function of time as an independent variable.

0.3 Use of the methods

The purpose of this extrapolation method is to estimate the following:

- a) The lower prediction limit¹⁾ (at 97,5 % probability level) of the stress which a pipe made of the material under consideration is able to withstand for 50 years at an ambient temperature of 20 °C using water or air as the test environment. In accordance with ISO 12162, the categorised value of this lower prediction limit is defined as MRS and is used for classification of the material.
- b) The value of the lower prediction limit (at 97,5 % probability level) of the stress, either at different design times or at different temperatures, or on occasion both. In accordance with ISO 12162, the categorised value of this lower prediction limit is defined as $CRS_{\theta,t}$ and is used for design purposes.

There are several extrapolation models in existence, which have different numbers of terms. This SEM will use only models with two, three or four parameters.

Adding more terms could improve the fit but would also increase the uncertainty of the predictions.

The SEM describes a procedure for estimating the lower prediction limit (at 97,5 % probability level) whether a knee (which demonstrates the transition between data type A and type B) is found or not (see Annex B).

The materials are tested in pipe form for the method to be applicable.

The final result of the SEM for a specific material is the lower prediction limit (at 97,5 % probability level) of the hydrostatic strength, expressed in terms of the hoop stress, at a given time and a given temperature.

For multilayer pipes, the determination of the long-term hydrostatic pressure strength of the products is carried out in accordance with ISO 17456.

For composite and reinforced thermoplastics pipes, guidance on the use of this method is given in the product standards.

Guidance for the long-term strength of a specific material with reference lines is given in the appropriate product standard.

1) In various ISO documents, the lower prediction limit (LPL) is defined incorrectly as the lower confidence limit (LCL), where LCL is the 97,5 % lower confidence limit for the mean hydrostatic strength.