

BULLETIN: GUIDING NORMS FOR THE PERFORMANCE OF PLASTIC PIPES



1 Introduction

This bulletin features a summary of international standards that set forth the evaluation, classification and use of plastics, with a special interest in Polyethylene pipe manufacturing. This review was specifically oriented towards ISO standards by means of inclusion of main standards that define the procedures for arrays, statistic analysis and nomenclature of classification of plastics for the manufacture of pipes, as well as the inclusion and explanation of some auxiliary standards relevant in the application of the main standard.

Upon the review of ISO standards, it has been identified the basic standards for the evaluation of plastic materials for the manufacture of pipes, as the standards specifically dedicated to Polyethylene pipes are:

- **ISO 12162:** Thermoplastic materials for pipes and joints for applications under pressure – Classification and Designation – Design Global Coefficient.
- **ISO 9080:** Thermoplastic pipes for fluids transportation. Extrapolation method of hydrostatic effort brake to obtain the hydrostatic resistance a long time of thermoplastic material for pipes.
- **ISO 1167:** Thermoplastic pipes for the transportation of fluids – Resistance to internal pressure – Array Methods.
- **ISO 4427:** Polyethylene pipes for water works – Characteristics.
- **ISO 4437:** Buried Polyethylene Pipes for the supply of gaseous fuels – Metrical Series – Characteristics.
- **ISO 13477:** Thermoplastic pipes for the transportation of fluids – Determination of resistance to rapid crack propagation – Small Scale Arrays in steady state (S4 array).
- **ISO 10837:** Determination of thermal stability of Polyethylene, for use in gas pipes and joints.
- **ISO 11420:** Method for the evaluation of dispersion grade of black smoke in pipes, joints and Polyolefin-made compounds.
- **ISO 13478:** Standard. Determination of resistance to rapid propagation of cracks (RPC) – Full Scale Testing (FST).

- **ISO 13479:** Method for the evaluation of the dispersion grade of pigments in pipes, joints and Polyolefin-made compounds.

2 General Principles and Standards that rule the performance of plastic pipes.

The feasibility of use of any pressurized plastic pipe is determined by the performance of the construction material under efforts, by considering the predicted service conditions (for example, high temperature, pressure levels, etc.).

2.1 ISO 12162 Standard:

This is the standard that regulates the classification and design of thermoplastic materials for manufacture of pipes and joints for pressure applications. This standard also provides a method to calculate design efforts.

Classification, material designation and calculation method are based on the internal pressure resistance with water at 20 °C for a 50 year period, derived by means of an extrapolation by using the specified method as set forth in the **ISO 9080** standard.

2.1.1 Reference Standards:

ISO 3: Preferred numbers: Series of preferred numbers.

ISO 497: Guidelines for the selection of series of preferred numbers and series that have more rounded values of preferred numbers.

ISO 1043-1: Plastics – Symbols – Part 1: basic Polymers and the special features thereof.

ISO 9080: Thermoplastic pipes for the transportation of fluids. Extrapolation method of hydrostatic effort brake to obtain the hydrostatic resistance a long time of thermoplastic material for pipes.

2.1.2 Definitions:

a) Long-term resistance at 20°C for a period of 50 years, σ_{LHTS} : Quantity with effort dimensions in MPa, which may be considered as a material property, and represents the lower limit of confidence of 50% for long-term resistance. σ_{LHTS} equals to the mean resistance or predicted mean resistance at 20°C during 50 years under internal water pressure.

b) Inferior confidence level at 20°C during 50 years, σ_{LCL} : Quantity with effort dimensions in MPa, that might be considered as a property of the material

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and represents the lower limit of confidence of 97.5% of the mean effort at the long term at 20°C during 50 years under water internal pressure.

c) Minimal Resistance Requires (MRS): σ_{LCL} value rounded to the closest minor value of R10 or R20 series pursuant ISO 3 norm, as well as ISO 497, depending on σ_{LCL} value.

d) Service Global (design) Coefficient C: Global coefficient with a value higher than 1, which considers service conditions, as well as the properties of the components of a pipe system, besides those represented in the lower level of confidence.

e) Design Effort, σ_s : Allowed effort for a determined application. It is derived by the MRS division into the Service Global Coefficient C , after rounding to the lowest proximate value of R20 series.

$$\sigma_s = \frac{[MRS]}{C}$$

2.2 Use of Standard Extrapolation Method (SEM). ISO 9080 Standard:

The use of SEM seeks the fulfillment of two basic requirements:

- Make an estimation of the average annular effort that the pipe material is considered to endure during 50 years under a room temperature of 20°C using water as the environmental test (σ_{LHTS}):
- Make an estimation of average annular effort value to shorter lifespan, higher temperatures or both combined conditions.

The final result of the SEM method for a specific material is the value of σ_{LHTS} and / or σ_{LCL} value (lower limit of the confidence interval for σ_{LHTS}). The required maximum resistance value MRS is obtained upon σ_{LCL} value. SEM method does not set forth the procedure to find the design admissible effort; neither specifies the safety factors that may apply.

SEM models are divided into Type I and Type II. Those of Type I are models of constant slope, whilst those of Type II are discontinuous change of constant slopes.

2.2.1 Type I Models:

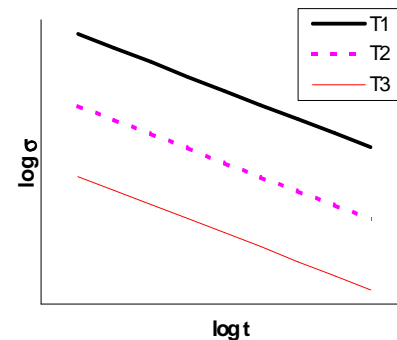


Figure 1. Schematic representation of 3-parameter Q1 model with constant slope

The equation of model QI comprises three parameters: A, B, C, based on the following expression:

$$\log t = -A - \frac{B}{T} \log \sigma + \frac{C}{T}$$

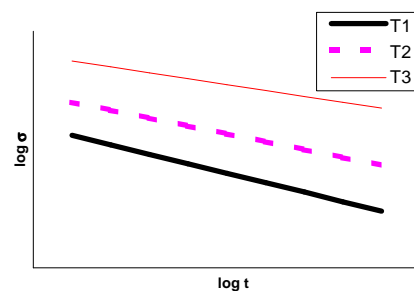


Figure 2. Schematic representation of RI model of four parameters with constant slope.

2.2.2 Type-II models

Equation of model RI comprises four parameters: A, B, C and D, according to the following expression:

$$\log t = -A - \frac{B}{T} \log \sigma + \frac{C}{T} + D \log \sigma$$

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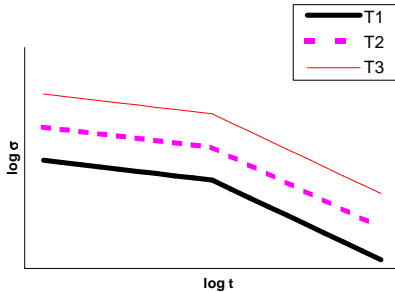


Figure 3. Schematic representation of model QII of six parameters with discontinuous change of constant slope.

Equation of model QII comprises of six parameters: A_1 , B_1 , C_1 , A_2 , B_2 , and C_2 , according to the following expression:

$$\log t = -A_1 - \frac{B_1}{T} \log \sigma + \frac{C_1}{T}$$

For zone (1); and

$$\log t = -A_2 - \frac{B_2}{T} \log \sigma + \frac{C_2}{T}$$

For zone (2).

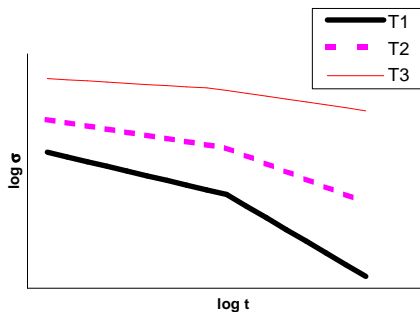


Figure 4. Schematic representation of model RII of eight parameters with discontinuous change of constant slope.

Equation of model RII comprises of eight parameters: A_1 , B_1 , C_1 , D_1 , A_2 , B_2 , C_2 , and D_2 , according to the following expression:

$$\log t = -A_1 - \frac{B_1}{T} \log \sigma + \frac{C_1}{T} + D_1 \log \sigma$$

For zone (1), and

$$\log t = -A_2 - \frac{B_2}{T} \log \sigma + \frac{C_2}{T} + D_2 \log \sigma$$

For zone (2).

Rupture effort data must be determined by the use of **ISO 1167** standard, except in those cases wherein there is a conflict with the SEM method.

The liquid that generates internal pressure in the pipe can be water or any other liquid that do not cause a chemical attack to the material, or induce its degradation. The external environment of the pipe can be air, water or any other liquid with the foregoing restrictions.

Internal and external temperatures must be maintained within $\pm 1^\circ\text{C}$ of the value of fixed temperature for the test.

The dimensions of the pipe (external diameter and wall thickness) must be measures pursuant **ISO 3126**.

2.2.3 Pressure level selection

For each value of temperature selected, a minimum of 25 points of failure effort-time as it is herein below shown:

Table 1. Pressure Level Distribution for Hydrostatic Tests

Hours	Failure Data
10-100	At least 8
100-1000	At least 8
Over 1000	At least 9
Over 7000	At least 4
Over 9000	At least 1

2.2.4 Selection of data gathering and analysis methods

ISO 9080 standard features two methods to obtain the long-term hydrostatic effort, (σ_{LHTS}). These methods are known as Method I and Method II.

The **Method I** is the most complete to determine the characteristics of rupture under pressure. This method

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requires the gathering of data under certain temperatures and terms long a year or more, and applies either there is a change of slope in the curve or not. The risk that the real behavior detours from the prediction of the extrapolation method is minimal, although is not zero. The **method I is appropriate to determine the rupture characteristics of new materials.**

The **method II** requires a minor experimental value range compared to method I in the number of levels of temperature to be evaluated, and the data must not indicate any slope change. This method is more convenient for the evaluation of new varieties of very well known materials in which the polymer has not been altered (for example a material previously evaluated in which the ratio of some additives was modified).

2.2.5 Description of Method I

Data is obtained pursuant the procedure and the aforementioned conditions, in which at least three temperatures $T_1, T_2, T_3 \dots T_N$, wherein $T_1 < T_2 < T_3 < \dots < T_N$ and the following additional conditions:

- Each couple of adjacent temperatures must be separated by at least 10 K.
- The highest temperature, T_{MAX} must not exceed the vitreous transition temperature in less than 20 K in amorphous materials, or predominantly amorphous, or the fusion temperature less than 15 K in crystalline or semi-crystalline materials.
- The maximum test temperature T_{MAX} must be selected by considering for each material the maximum temperature that such material could be used, as well as the possible maximum test temperature.

2.2.6 Detection in the change of slope; data validation and model.

ISO 9080 standard employs a mathematical test to the linear regression to determine the presence of changes in the slope of a curve. A linear regression is applied to the gathered data for each temperature separated, and the slope of the regression line is determined, and the effort in which the 50% and 2.5% of fail is predicted after 50 years (it means, σ_{LHTS} and σ_{LCL} values).

If one or more temperatures in the regression slope is positive, it is considered that the data to such temperature are inadequate.

The method described in the standard is applied to determine the change of slope. If the change is confirmed, one out of both model II must be used. If changes are not detected, type-I models must be used. Once selected the type of model, the selection of the adequate model (Q or R) depends on the statistical test of lack of fit, in which the statistical value F is obtained, and the model that provides a minor value is chosen. If F is over 20 for both cases, the model must be considered inadequate.

2.2.7 Description of Method II

Data is obtained according to the procedure, and the described conditions, at two temperatures T_1 and T_2 , wherein T_2 must be at least 40 K higher than T_1 , and the number of observations and the pressure distribution must be made pursuant Table 1. The rest of the procedure is similar to method I.

2.3 ISO 1167 Standard

This standard specifies the method to determine the resistance of thermoplastic pipes to water internal pressure under constant temperature. Arrays performed to determine the classification of PE pipes must follow the procedures set forth in this standard.

The standard has an informative attachment wherein the **recommended failure times** are specified for each level of pressure (or annular effort). The standard indicates that pipe failure times must not be less than the minimal specifies time in the chart. However, Table 2 has a marginal note that explain "if a material with a default MRS value according to ISO 9080 standard by means of the required array series, do not comply with the minimal test time specified in the table, test times can be modified and the materials with a given MRS that physically do not comply with the specified requirements for 80°C a minor value could be used, according to Table 3. ISO 1167 standard contains the detailed procedure for the execution of hydrostatic tests, and indicates a series of short-to-medium lasting tests (until 42 days) that even if allow to determine a preliminary profile of the features of hydrostatic resistance desired in materials

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for pipes, **cannot be used for a definite classification of the material.**

Table 2. Recommended Failure time for PE Pipes.

Material	Test Effort (MPa)		
	100 h @ 20°C	165 h @ 80°C	1000 h @ 80°C
PE 100	12.4	5.5	5.0
PE 80	9.0	4.6	4.0
PE 63	8.0	3.5	3.2
PE 40	7.0	2.5	2.0
PE 32	6.5	2.0	1.5

2.4 ISO 13479 – Determination of resistance to propagation of cracks. Test method for slow growth of cracks in slotted pipes (slot test).

In this array, pipes with a determined longitude with four longitudinal machine-made slots are put under constant hydrostatic pressure while submerged in water at 80°C. Failure time is registered. Equipments and procedures applied for the hydrostatic test are those set forth in ISO 1167 standard. The slot is made by means of a milling machine with a horizontal mandrel fixed to a base in order to fixate properly the tube, and therefore achieve a straight slot. The blade must have a "V" angle of 60° according to ISO 6108 standard, with a cutting speed of 0.010 ± 0.002 (mm / rev) / teeth. For example a blade with 20 teeth rotating to 700 rpm, must move to a speed of 150 mm / min, with a cutting speed of $150 / (20 \times 700) = 0.011$ (mm / rev) / teeth.

With:

$$p = \frac{10\sigma}{S}$$

Or:

$$p = \frac{20\sigma}{(SDR - 1)}$$

Wherein:

σ : Hydrostatic effort (equivalent to the annular effort in MPa).

S. Pipe Series

SDR: Dimension standard quotient: $\frac{d_n}{e_n}$

The standard recommends a minimum of three arrays, wherein there must not be any failure within a term of 165 h, it means, 7 days.

There is the possibility to perform a slow cracking array with test tubes extracted from pipes, by means of a procedure described by Tränkner, in which test tubes are submitted to a constant effort, following a similar principle to the PENT array, upon the standard ASTM F 1473.

2.5 ISO 13477 standard. Determination of resistance to rapid propagation of cracks (RPC) – Steady test in small scale (S4 Array)

The principle of this array comprises in submitting a section of pipe, pressurized and kept under controller temperature, to an impact in a proximal end, in order to start a longitudinal crack with a fast growth. The required equipment to perform the test is described in the document of the standard, and comprises of a container cage that restricts the radial expansion during the crack while allowing the expansion during the stage of internal pressurization, a measure zone, internal fins for a internal support zone to avoid the deformation of the walls of the pipe during the impact, and the starting kit of the crack, which comprises of an impact blade with dimensions and specific characteristics.

The purposes of the array are:

- Obtain the value of critical pressure (or critical annular effort) in which the quick spread of the crack is produced.
- Obtain the critical temperature of propagation of cracks. Critical temperature is defined as the lowest temperature produced by the detention of the crack. A slightly lower temperature than the critical temperature would produce a quick spread of the crack.

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2.6 ISO 13478 Standard. Determination of resistance to rapid propagation of cracks (RPC) – Full Scale Testing (FST).

The principle of this array is the same as that of ISO 13477 standard. A track of pipe made with a thermoplastic material, kept with an internal pressure and specific temperature, is submitted to impacts designed to begin the formation of cracks. ISO 13478 standard differs from 13477 in the use of a larger equipment for pipes with a minimum length of 14 meters. The objectives, as those from 13477 are:

- a) Obtain the value of critical pressure (or critical annular effort) in which the quick spread of the crack is produced.
- b) Obtain the critical temperature of propagation of cracks. Critical temperature is defined as the lowest temperature produced by the detention of the crack. A slightly lower temperature than the critical temperature would produce a quick spread of the crack.

3 Summary

ISO 12162 standard sets forth the criteria for the classification of plastic materials for pipe manufacturing, pursuant determined MRS values by following the procedures of ISO 9080 standard. The procedure for the determination of MRS requires the assembly of at least 25 hydrostatic testing that last between a few hours until 9000 hours, it means, over a year. ISO 1167 standard contains a detailed procedure for the execution of hydrostatic testing, and indicates a series of short and medium duration (until 42 days) that allow to establish a preliminary profile of the desired hydrostatic resistance in materials for pipes, but it cannot be used as a final material classification.

4 References

1. International Standard ISO 13949. Method for the assessment of the grade of pigment dispersion in polyolefin pipes, pipes and compounds.
2. International Standard ISO 13479. Polyolefin pipes for the conveyance of fluids - Determination of the

resistance to crack propagation - Test method for slow crack growth on notched pipes (notch test).

3. International Standard ISO 13478 - Thermoplastic pipes for the conveyance of fluids - Determination of the resistance to rapid crack propagation (RCP) - Full scale test (FST)
4. International Standard ISO 13477. Thermoplastic pipes for the conveyance of fluids - Determination of the resistance to rapid crack propagation (RCP) - Small-scale steady-state test (S4 test)
5. International Standard ISO 12162 - Thermoplastic materials for pipes and fittings for pressure applications - Classification and designation - Overall service (design) coefficient.
6. International Standard ISO 4437. Buried polyethylene (PE) pipes for the supply of gaseous fuels - Metric series – Characteristics
7. International Standard ISO 4427. Polyethylene (PE) pipes for water supply - Characteristics.
8. International Standard ISO 11420. Method for the assessment of the grade of carbon black dispersion in polyolefin pipes, fittings and compounds.
9. International Standard ISO 1167. Thermoplastic pipes for the conveyance of fluids – Resistance to internal pressure - Test method.
10. International Standard ISO 10837. Determination of the thermal stability of polyethylene (PE) for use in gas pipes and fittings.
11. International Standard ISO/TR 9080. Thermoplastic pipes for the transport of fluids - Methods of extrapolation of hydrostatic stress rupture data to determine the long-term hydrostatic strength of thermoplastics pipe materials.
12. Tränkner, T. Slow crack growth test as a ranking method, Studsvik Polymer AB, Sweden.
13. Ifwarson, M, Leijstrom, H, What controls the lifetime of plastic pipes and how can the lifetime be extrapolated. Studsvik Polymer AB, Sweden.
14. ASTM Standard test method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials. Annual Book of ASTM Standards, 1992.
15. Solvay Polymers, ASTM vs. ISO Methodology for Pressure Design of Polyethylene Piping Materials.

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Table 3. Hydrostatic Pressure at 80°C – Requirements for Repetition of tests

PE 32		PE 40		PE 63		PE 80		PE 100	
MPa Effort	Minimum Fail time h	MPa Effort	Minimum Fail time h	MPa Effort	Minimum Fail time h	MPa Effort	Minimum Fail time h	MPa Effort	Minimum Fail time h
2,0	165	2,5	165	3,5	165	4,6	165	5,5	165
1,9	227	2,4	230	3,4	285	4,5	219	5,4	233
1,8	319	2,3	323	3,3	538	4,4	283	5,3	332
1,7	456	2,2	463	3,2	1000	4,3	394	5,2	476
1,6	667	2,1	675			4,2	533	5,1	688
1,5	1000	2,0	1000			4,1	727	5,0	1000
						4,0	1000		

This bulletin has been elaborated by the Marketing Management of Polinter, with the support of specialists of Investigación y Desarrollo, C.A. (INDESCA), and the Technical Services Management of CORAMER. It is intended to all the users of Venelene resins and we trust that the information herein contained will be useful.

In case of comments or suggestions, please write to info@polinter.com.ve or contact our Commercial Agent at <http://www.coramer.com>

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