POSITION PAPER

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100 years lifetime of Polyethylene pressure pipe systems buried in the ground for water and natural gas supply

1. Introduction

TEPPFA and PE100+ Association have identified the need for explaining the difference between the design point at 20 degree/50 years and the expected life-time of PE80 and PE100 pressure pipe systems. Research, extrapolation studies and reports on dig-up pipes in service show minimal degradation and extrapolative tests performed on these test samples confirm an expected service life in excess of 100 years.

2. Design vs. service life

Design life must not be confused with the actual lifetime of a PE pressure pipe system. In real life, the service life is expected to be more than 100 years due to a number of reasons,

- Lower real pressure level (stress) over the whole lifetime
- Lower real temperatures in the ground
- Tolerances for wall thicknesses are always in the zero to “plus” tolerance range
- In the design stage a safety factor is applied

3. Design basis of PE pressure pipe systems

The 50 year design basis and minimum service life for a PE pressure water or gas pipe systems is secured through the established standards ISO 9080[1] and ISO 12162[2]. ISO 9080 provides an extrapolation method to estimate the 97.5% lower

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prediction limit of the stress (σ_{LPL}) which a thermoplastic pipe is able to withstand for 50 years at 20°C. Extrapolation is made from data obtained through hydrostatic pressure tests carried out at different temperatures in accordance with ISO 1167-1[3] and ISO 1167-2[4]. ISO 12162 establishes a classification and designation system for thermoplastic pipes, based on their minimum required strength (MRS) derived from their σ_{LPL}. A PE pipe with 8 MPa $\leq\sigma_{LPL}$<10,0 MPa has a MRS of 8 MPa and is designated as PE 80. A PE pipe with 10 MPa $\leq\sigma_{LPL}$<11,2 MPa has a MRS of 10 MPa and is designated as PE 100. ISO 12162 also specifies a method for calculating the design stress σ_S from the MRS and a design coefficient C (σ_S=MRS/C). Unless otherwise specified in a specific product standard, a minimum design coefficient (C_{min}=1.25 for PE80 and PE100 water and C_{min}=2 for PE80 and PE100 gas) is used.

The product standard series of ISO4427[5] as well as the EN12201[6] specifies the specific requirements for a modern solid wall PE80 and PE100 pressure piping system and its components intended for the supply of water under pressure. In the last draft edition series, the scope of ISO 4427 of water for human consumption has been extended to raw water prior to treatment, drainage and sewerage under pressure, vacuum sewer systems and water for other purposes.
The product standard series of ISO4437[7] as well as the EN1555[8] specifies the specific requirements for a modern solid wall PE 80 and PE100 pressure piping system and its components intended for the supply of natural gas under pressure, mainly used for the distribution and house connection systems up to 10 bar for PE100.

It is recognized in standards (reference 5,6,7 and 8), that “research on long term performance prediction of PE water and gas distribution systems shows a possible service life of at least 100 years”.

Whilst initial material improvements increased the pressure resistance (PE 63 to PE 80 and to PE 100), considerable progress has been made in recent years by increasing the resistance to slow crack growth (SCG). This designated PE100-RC (RC: Raised Crack resistance) piping material requires a separate number of tests to assess the SCG performance; whilst all other material and product requirements of PE100-RC are identical to the well-known and established PE 100. Piping systems made of a PE100-RC material can be used for alternative installation methods, for example when more surface damage might be encountered or for installations where excavated soil is used as bedding material (extract from prEN1555-1 Annex A).9 All 4 of the above mentioned application standard series

will include PE100-RC in their next revision in the coming years, starting with the EN1555 series.

4. Publications and Dig-up studies proving a 100+ year service life for PE pressure pipe systems

Polyethylene material developments started around 1953 with the first generations of PE40, PE50 and PE63; these materials have exceeded 50-70 years service life and are partially still in service. Today markets are using PE80 materials mainly due to its flexibility and ease of installation especially in smaller dimensions, but the majority has moved over to PE100 rated systems in the last 30 years. Pipes for water can be extruded in sizes of 16mm up to 3500mm. PE gas pipe systems are in use since about 60 years with very low failure rates even under ground-movement conditions. Gas pipe size reach from 16mm up to 800mm.

Many dig-up reports have been published or presented in conferences about the mechanical performances of PE pressure pipes covering a variety of decades of continuous service conditions, locations and applications. Many PE pipe systems have already exceeded the end of the specified design life point of 50 years, without any indication within the failure statistics maintained by the utilities of any age-related reason. Examples are listed below:

> At the Plastic Pipes XIII in Washington in 2006, Schulte[10] reported that pipes produced in 1956 and installed in October of the same year in a pressure-testing rig had actually passed 50 years of successful testing as predicted. Further examples of the longevity of PE pipes are given in this paper together with an assessment of latest generation pipe resins, showing potential for application extension to 100 years.
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> In 1997 U. Schulte[11] showed, that with standardized extrapolation method ISO/TR 9080 a service life of over 100 years can be expected for bimodal PE-HD types.
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> In 2007 J. Hessel[12] summarized the investigations on used pipes from 1st generation HDPE and calculated already high residual service life for these pipes. Due to the extreme material improvements in stress crack resistance a minimum service life of 100 years is proven for advanced PE100 materials (PE100-RC). The thermal ageing is taken into account and was tested at higher temperatures. With the “Arrhenius” law a failure time due to thermal aging of more than 460 year for service temperature 20°C was calculated.

In 2009 H. Brömstrup[13] published the third edition of the booklet “PE100 Pipe systems” and concludes on pages 34-35 that the bimodal PE100 materials can be considered valid for a 100year lifetime.

Japan Polyethylene Piping system & Integrated Technology Association for water Supply (Politec[14]) conclude based on extrapolation of results and calculations that there is a safe design concept to conclude on a 100 year practical lifetime.

J.M.B. Sanders[15] concludes that the life of a service pipe exceeds 100 years based on different methods applied, investigation of the additive level remained via OIT method and analyzing the failure mode in the different stages.

U.K. Water Industry (prepared and published by WRc[16]), concludes a 100-140 years expected lifetime based on PE80 MDPE pipes investigated at different temperatures 20°C, 60°C and 80°C for 13years and extrapolated stress rupture curves.

In major markets like Europe, Russia, Africa, Middle East and South America, ready-made black and coloured PE pipe compounds are provided by the resin manufacturers with little or no variation in formulation over the years. The performance based EN and ISO PE pipe application standards are designed with safety margins and the quality systems in place at the PE pipe manufacturers ensures a traceability of the raw materials used. The above consistent results obtained across all regions, demonstrate that a reliable service in excess of 100 years can be expected when a readymade compound is used in the quality pipe production process and the installation has followed the industry standards.

Literature references

[1] ISO 9080:2012 “Plastics piping and ducting systems-Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation”.

[2] ISO 12162:2009 “Thermoplastics materials for pipes and fittings for pressure applications-Classification, designation and design coefficient”.

[3] ISO 1167-1:2006 “Thermoplastics pipes, fittings for the conveyance of fluids-Determination of the resistance to internal pressure-Part 1: General Method”.

[4] ISO 1167-2:2006 “Thermoplastics pipes, fittings for the conveyance of fluids-Determination of the resistance to internal pressure-Part 2: Preparation of pipe test pieces”.

[5] ISO4427-1 to ISO4427-5 series “Plastic piping systems for water supply and for drainage and sewerage under pressure –Polyethylene (PE)”.

[6] EN12201-1 to EN12201-5 series “Plastic piping systems for water supply and for drainage and sewerage under pressure –Polyethylene (PE)”

[7] ISO4437-1 to ISO4437-5 series “Plastic piping systems for the supply of gaseous fuels –Polyethylene (PE)”.

[8] EN1555-1 to EN1555-5 series “Plastic piping systems for the supply of gaseous fuels –Polyethylene (PE)”

[9] prEN1555-1 to EN1555-5(2019) series “Plastic piping systems for the supply of gaseous fuels – Polyethylene (PE)”

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[16] U.K. Water Industry Information & Guidance Note IGN 4-32-18 March 2003:1 Issue 1 (Page 1-17) ISSN 1353-2529 (reprint June 2006 web publication) The choice of pressure ratings for Polyethylene pipe systems for water supply and sewerage duties

About TEPPFA

TEPPFA is founded in 1991 in Brussels and is the trade association for the plastic pipe and fitting industry in Europe. Via direct members and National Associations, we are representing more than 400 manufacturers of plastic pipe systems and also have resin manufacturers as members. More at: www.teppfa.eu.

About PE100+

Founded in 1999, the PE100+ Association is an industry organisation of 13 polyethylene (PE) manufacturers (status 2019).

Their objective is to promote ready-made coloured PE80 and PE100 compounds of consistent quality at the highest level for the production of polyethylene pressure pipes and focuses on providing support for end users, thereby enhancing trust in PE piping systems. The PE100+ Association issue a "PE100+ Quality Materials list" verified through regular third party testing of selected, critical material properties for PE100 materials. More at: www.pe100plus.com