WHITE PAPER

MINIMUM PERFORMANCE REQUIREMENTS OF HDPE PRESSURE PIPES

Dr. Jeroen Wassenaar
Market Segment Manager
Dr. Predrag Micic
Product Development Executive
November 2020

–
Find out what it takes for HDPE pipes to last 50 years or more.
–

Product and installation standards for HDPE pressure pipes have been established to ensure a target design life of at least 50 years under typical application conditions. It is essential that all actors involved in pipe value chain have a basic understanding of the minimum performance requirements listed in the standards and how conformance to the standards is assured. Failure to consistently meet the requirements may result in the structural integrity of the pipeline being compromised, service disruptions and ultimately a need for expensive replacement of pipe. As HDPE pressure pipes make their way into new applications, and new installation techniques emerge, additional requirements need to be considered to keep the target design life above 50 years.

HDPE PRESSURE PIPE IS ONE OF THE MOST POPULAR SYSTEMS USED FOR WATER AND GAS DISTRIBUTION NETWORKS. HDPE PRESSURE PIPE IS ALSO WIDELY USED IN A RANGE OF INDUSTRIAL APPLICATIONS INCLUDING MINING AND OIL & GAS. THE WIDESPREAD ADOPTION OF HDPE PRESSURE PIPE IS LARGELY ATTRIBUTABLE TO THE HIGH INTEGRITY OF THE SYSTEM THAT IS GOVERNED BY STRICT PERFORMANCE STANDARDS AND QUALITY ASSURANCE (QA) THAT IS SUPPORTED BY THIRD PARTY CERTIFICATION.

Performance and QA requirements need to be understood by the entire value chain, from raw material producer to asset owner. They also needs to be embedded in all company quality systems, including procurement practices and job tenders. Failure to consistently meet the performance requirements specified in relevant product and installation standards may result in the integrity of the system being compromised, leading to service disruptions, expensive repairs and in some cases risk of injury.

The aim of this white paper is to provide a basic overview of the requirements of the HDPE pipe standards and how conformance to these standards can be verified. The paper also highlights cases where performance beyond standard requirements is advisable.

The minimum requirements for polyethylene pipes used for pressurised water and gas distribution in Australia and New Zealand are provided in AS/NZS 4130:2018.

Table 1 shows an extract of the key performance requirements specified in the standard. AS/NZS 4130:2018 incorporates the requirements for raw material specified in AS/NZS 4131:2010.

The purpose of the performance standards is to ensure a minimum design life for HDPE pressure pipes of 50 years under typical installation conditions. Some of the key attributes of pressure pipe compounds per the standards are listed in Table 2.

PIGMENT DISPERSION

The raw material used in the manufacture of HDPE pipe must be a fully formulated compound containing antioxidants, UV light stabilisers and pigments.

Typically, carbon black fulfills the roles of both UV light stabiliser and pigment. The mixing of carbon black needs to be tightly controlled to ensure uniform dispersion within the polymer and protection against loss of properties of the pipe when exposed to UV.

Good dispersion of carbon black is best achieved in an intensive mixing process in a dedicated mixer when the pipe grade resin is being produced. A technically complex manufacturing process is needed to ensure sufficient carbon black content and adequate dispersion without overworking/degrading the material.

Deveci and co-workers have demonstrated that mixing of carbon black masterbatch (CBMB) with a natural HDPE pipe resin in a conventional pipe extruder may result in inadequate dispersion of the carbon black even at reduced extrusion speed (Figure 1).[1] Through tensile testing, the study showed that the pipe samples with inadequate carbon black dispersion exhibited brittle failure and severely reduced elongation at break.

TABLE 1. KEY PERFORMANCE ATTRIBUTES OF PRESSURE PIPES ACCORDING TO AS/NZS 4130:2018 (NON-EXHAUSTIVE).

ATTRIBUTE	METHOD	REQUIREMENT
Classification	N/A	PN3.2 – PN25 depending on SDR and compound classification (PE100 or PE80)
Composition	N/A	Fully pre-compounded pipe extrusion compound according to AS/NZS 4131
Rework material	N/A	Only clean internal rework material from the same grade of resin is permitted
Striping/Jacketing compound	N/A	Needs to be manufactured from base resin compound conforming to AS/NZS 4131. Needs to contain at least 0.2% of HALS. AS/NZS 4131 thermal stability and dispersion requirements apply.
Dimensional tolerances	AS/NZS 1462.1	Wall thickness and out of roundedness will need to be within tolerances allowed in AS/NZS 4130 depending on pipe diameter and SDR
Effect on water	AS/NZS 4020	Pass. Surface area/volume ratio used in test specimens to be reported.
Resistance to internal pressure	AS/NZS 1462.6	PE100: > 165 hours (@80°C, @5.4MPa) PE80: >165 hours (@80°C, @4.5MPa)
Thermal stability	ISO 11357-6	>20 min (@ 200°C)
Slow crack growth resistance	ISO 13479	PE100: > 500 hours (@80°C, @920kPa) PE80: > 500 hours (@80°C, @800kPa)

TABLE 2. KEY PERFORMANCE ATTRIBUTES OF PRESSURE PIPE COMPOUNDS ACCORDING TO AS/NZS 4131:2010 (NON-EXHAUSTIVE).

ATTRIBUTE	METHOD	REQUIREMENT
Compound	N/A	Compounds shall be manufactured from polyethylene containing antioxidants, UV stabilisers and pigments necessary for their manufacture into pipes and fittings. Additives containing lead (Pb), cadmium (Cd) or mercury (Hg) shall not be used.
Thermal stability	ISO 11357-6	>40 min (@ 200°C)
Dispersion	AS/NZS 1462.28	Average maximum size of pigment agglomerates ≤ 60μm (Grade 3)
Volatile content	EN 12099	≤ 350 mg/kg
Classification	AS/NZS 1462.29	PE100: MRS > 10.0MPa (@ 20°C) PE80: MRS > 8.0MPa (@ 20°C)
Rapid crack propagation resistance	ISO 13477	PE 100: critical pressure > 1.0 MPa PE80: no requirement
Resistance to internal pressure	AS/NZS 1462.6	PE100: > 165 hours (@80°C, @5.4MPa) PE80: >165 hours (@80°C, @4.5MPa)
Slow crack growth resistance	ISO 13479	PE100: > 500 hours (@80°C, @920kPa) PE80: > 500 hours (@80°C, @800kPa)
Effect on water	AS/NZS 4020	Pass. Surface area/volume ratio used in test specimens to be reported.

> IT IS OF EXTREME IMPORTANCE TO MONITOR OXIDATION INDUCTION TIME (OIT) AND INVESTIGATE ANY SIGNIFICANT DECREASE FROM COMPOUND TO PIPE DURING MANUFACTURE, EVEN IF THE PIPE STILL MEETS THE MINIMUM OIT VALUE DEFINED IN THE STANDARD.

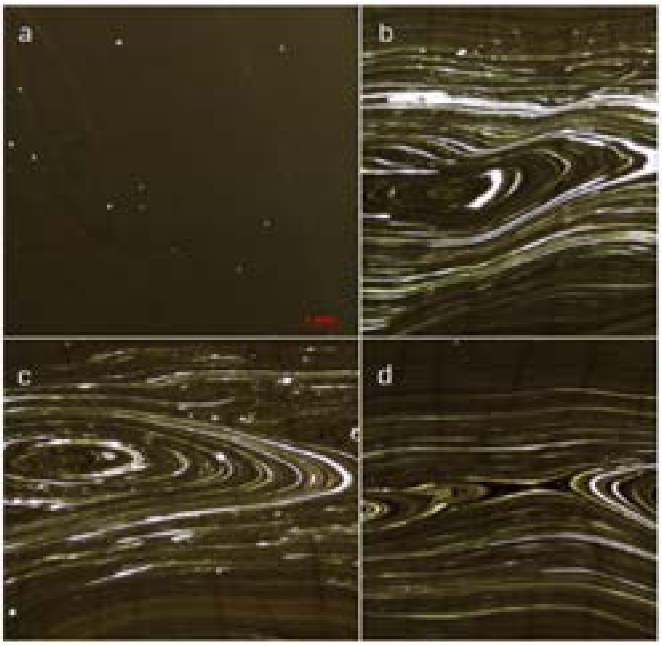

Figure 1. Microscopy images of 15µm slices (cross-flow) taken from pipe specimens made from: (a) pre-compounded black PE100 at 100% extrusion speed, (b) natural resin + CBMB at 100% extrusion speed, (c) natural resin + CBMB at 80% extrusion speed and (d) natural resin + CBMB at 60% extrusion speed. Image reproduced with permission of authors in reference 1.

THERMAL STABILITY

Thermal stability needs to be measured at both compound and pipe stage. The thermal stability results show if the antioxidant package is effective at providing short-term protection during pipe manufacture.

The data also provide information on the adequacy of any long-term protection against degradation for pipe that is in service. ISO 11357-6 standard uses Oxidation Induction Time (OIT) to measure thermal stability of the compound and pipe.

For pipe samples, OIT should always be measured at the inner wall. The standard specification for OIT allows for some decrease from compound to pipe (OIT 20 min on pipe vs 40 min on compound). However, field experience shows that in a well-controlled pipe manufacturing process, the OIT value remains largely unaffected from polymer to the produced pipe.

It is therefore of extreme importance to monitor Oxidation Induction Time (OIT) and investigate any significant decrease from compound to pipe during manufacture, even if the pipe still meets the minimum OIT value per the standard. This is illustrated in the set of commercial pipe extrusion runs summarised in Table 3.

Modern PE100 compounds will exhibit a minimal drop in OIT performance if extruded at melt temperatures below 230°C.

Increasing the pipe size will typically result in a larger drop in OIT, as the material in a thicker wall takes longer to cool and the surface of the pipe is exposed to oxygen at an elevated temperature for longer.

Increasing extruder throughput will result in higher melt temperatures, which may also adversely impact OIT. However, the melt temperature of different pipe compounds react differently to increases in extruder throughput.

TABLE 3. INFLUENCE OF COMPOUND, MELT TEMPERATURE AND EXTRUDER THROUGHPUT ON OIT OF PIPE EXTRUSION PROCESS ON A BATTENFELD 120MM LINE. THE OIT VALUES ON PIPE ARE THE AVERAGE OF MEASUREMENTS TAKEN FROM THE INSIDE TOP AND INSIDE BOTTOM SAMPLE POSITIONS OF THE PIPE.

PIPE COMPOUND	PIPE SIZE	MELT TEMPERATURE (°C)	EXTRUDER THROUGHPUT (KG/HR)	OIT @ 200°C TO ISO 11357-6 (MIN)
Alkadyne HDF145B (discontinued grade)	Compound	–	–	80
	DN450 SDR13.6	200	800	78
	DN450 SDR13.6	206	1150	78
Alkadyne HDF193B	Compound	–	–	81
	DN450 SDR13.6	209	800	83
	DN450 SDR13.6	220	1000	74

REWORK LIMITATIONS

Given the risk profile of pressure pipe applications, only internal rework using the same grade of resin is allowed during pipe extrusion. To prevent the introduction of contamination that might compromise pipe quality and expected service life, the incorporation of external rework or reground decommissioned pipes is strictly prohibited. Ensuring the integrity of product representation is another reason that different polymer grades should not be mixed. Pressure pipe is a highly regulated infrastructure and construction market segment. New or modified pipe compound grades are only commercialised following the completion of extensive Type Testing programs. These programs cover testing for all performance properties and ensure that newly developed pipe compounds meet the application requirements.

MOISTURE CONTENT

High levels of volatile content in the resin (in practice this is predominantly water) can lead to holes in the pipe wall or cause an uneven surface on the internal wall of the pipe, resulting in non-compliant pipes (Figure 2). Carbon black is a hygroscopic material that absorbs water if stored for long periods of time without adequate precautions. The water will evaporate during the melting process but cannot escape until it exits the extrusion die. While most compound manufacturers have adequate procedures in place to dry the product below the standard requirement, moisture may be introduced during transport of the resin to the pipe manufacturer. This is a particular problem during sea freight across the equator, due to a phenomenon known as "container rain" that can cause the product to fall out of specification.[2] The last line of defence is to dry the resin at the pipe manufacturing site before it enters the extrusion process. An effective drying system heats the resin at an elevated temperature while blowing through an optimised flow of dehumidified air.

PERMITTED COMPOUND CLASSIFICATIONS

Pipes manufactured according to AS/NZS 4130 only allow the use of pipe compounds classified as PE100 or PE80. These two classes of compounds differ in terms of hydrostatic strength, rapid crack propagation resistance and resistance to slow crack growth.

Since PE100 has higher performance requirements than PE80 in all these areas, pipes made from PE100 for the same pressure class have a lower wall thickness or higher standard dimension ratio (SDR = nominal diameter/wall thickness).

HDPE pipe materials of different classification based on a single property are not recognised by pipe application standards in Australia or in any other country that adheres to ISO standards. Certain materials designated as PE112 can be used to make PE100 pipes if they meet the minimum requirements for a PE100 compound. However, the use of PE112 will not result in any design or performance benefit for standard compliant HDPE pressure pipes as operating the pipe beyond the maximum allowable operating pressure for PE100 is not covered by Australian or International pipe product standards. ISO technical committee TC138/ SC4 concluded in 2000 that no further standardisation work would be done on PE112.[3]

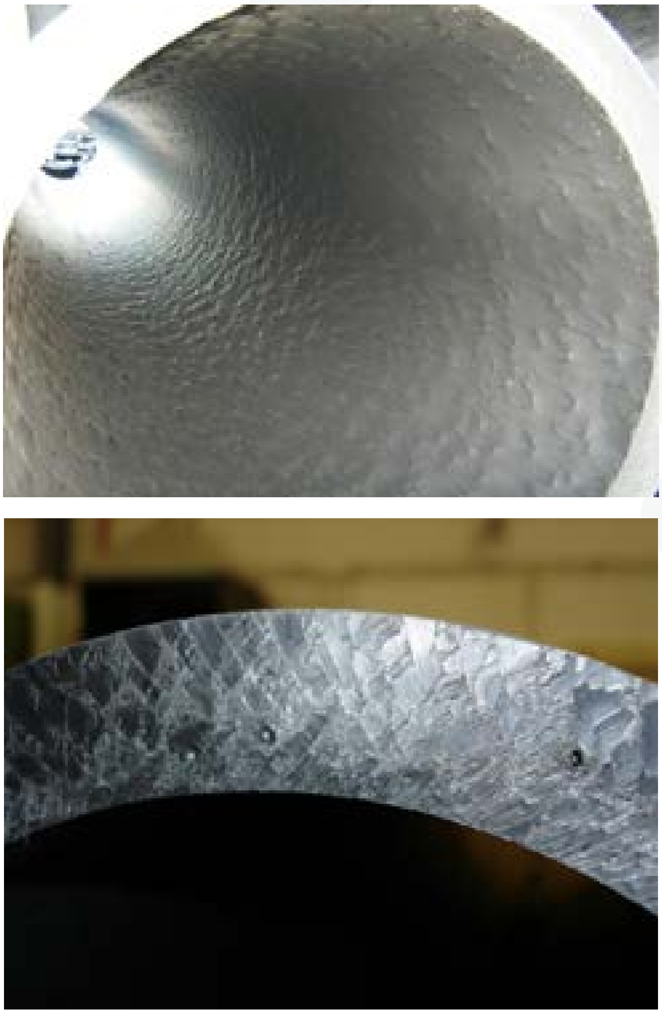

Figure 2. Example of pipe extruded from a resin with elevated moisture content resulting in uneven inner pipe wall (top) and holes in the pipe wall (bottom).

DIMENSIONAL TOLERANCES

Dimensional tolerances of pipes in terms of wall thickness variation and out of roundness are specified within AS/NZS 4130. While most modern pipe extrusion lines are capable of controlling these parameters within tight tolerances for wall thicknesses up to 60mm, manufacturing of large bore pipes with a greater wall thickness can still present a challenge, even to experienced manufacturers.

As polyethylene is a good thermal insulator, the time required to cool from the molten to the solid state increases with increasing wall thickness. During cooling, the molten polymer may be deformed by gravity or by an uneven flow, leading to slumping of the pipe (Figure 3).

Slumping can be avoided using a pipe compound with low slump properties. Low slump resins have a high melt strength which ensures that the shape of the die is maintained when the molten polymer exits the die head.

As larger pipe diameters and higher pressure ratings are becoming more commonplace, the requirement for tight dimensional tolerance control through low slump compounds is increasing.

Figure 3. **Example of DN500 PN25 pipe made with standard PE100 resin (top), showing severe slumping, and a pipe made within dimensional tolerance produced with a low slump PE100 resin (bottom).**

WATER QUALITY

It is essential that any pipe material used to distribute drinking water does not adversely impact the quality of the water. The AS/NZS 4020 standard requires that HDPE pipes (and other water contact products) are assessed for their effect on water. The test consists of exposing a fixed volume of cold water (<40°C) inside a small diameter pipe. The water extract is then tested for taste, appearance, toxicity and metal content. The results depend on the internal diameter of the pipe used in the test, as the surface contact area increases with decreasing diameter. Typically, a DN25 mm is used in the test, however, in practice HDPE pipe diameters as narrow as DN16 mm are used in water reticulation. Therefore, some end users will require water tests to be done on DN16 mm pipe, which represents the most challenging condition to meet the requirements of the AS/NZS 4020 standard.

HOW TO VERIFY CONFORMANCE

Given the highly technical nature of the requirements of pipe standards, third-party certification is a practical way for all actors in the pipe value chain to assess a material's conformance to the relevant standard. The standard also requires regular testing of products.

The test frequency depends on the test concerned, with some tests needed on every batch (Batch Release Test = BRT), some at an interval of 3 or 5 years (Process Verification Test = PVT), while some are only required when assessing a new or changed product (Type Test = TT).

Pressure pipe compounds are assessed upon application by PIPA (Plastic Industry Pipes Association of Australia) against AS/NZS 4131. If the compounds are compliant, they are listed in the POP004 guideline.[4]

The assessment also includes compliance with temperature rerating per POP013 and high stress-crack resistance (PE100 HSCR) per POP016. However, the listing does not guarantee that PVT or other tests are being undertaken at prescribed intervals, nor is there an audit of the manufacturing site.

Nonetheless, the POP004 list represents a credible and valuable check as to whether a pipe compound complies with the Australian standard.

Another way to verify compliance of pipes or compounds with the relevant standard is via Type Test Certification through a JAS-ANZ accredited certification body. These organisations assess conformance of a product to a recognised standard based on product tests from an ISO 17025 accredited test facility.

If requested, they will also perform an audit to assess the quality management plan to ensure the ongoing compliance of every batch produced. Type Test Certification allows manufacturers to use conformance statements and license marks on their product documentation to demonstrate product standard conformity along the value chain.

For plumbing products sold in Australia, certification is mandatory and regulated through the WaterMark of the Australian Building Codes Board (ABCB). WaterMark certification is available through accredited certification bodies.

The Water Services Association of Australia (WSAA) product appraisal scheme is a complementary program for infrastructure pipes. It assesses product conformity, design life and product use, including installation and maintenance.

EXCEEDING STANDARD PERFORMANCE

Product standards set the minimum requirements and any products that comply with the standards are expected to be fit for purpose in most applications that are covered by the standard. However, this does not mean that the product will be fit for purpose in every application and under all conditions encountered.

The use of HDPE pipe has become increasingly popular for industrial and mining applications where it can provide significant cost and performance benefits, such as corrosion resistance, rapid installation and abrasion resistance, compared to traditional materials. However, in many of these applications, temperatures will exceed the typical installation conditions of civil construction projects. Compliance to temperature rerating per PIPA POP013 will be important in these more-extreme applications. When high levels of temperature resistance are required, specialty PE100 Raised Temperature (RT) resins are available that can provide long term resistance to temperatures in excess of 70°C.

Pipe installation in urban environments is increasingly carried out using trenchless techniques such as horizontal directional drilling or pipe bursting. These installation methods put higher demands onto HDPE pipe due to the increased risk of damage to the pipe wall or presence of point loads that could lead to slow crack growth failure. Pipes with high stress-crack resistance made using a PE100 HSCR compound conforming to PIPA POP016 can mitigate such risks and will exhibit longer expected design life in such demanding installations.

Another environment in which conformance to minimum requirements is not sufficient to meet design life expectation is in applications where elevated water temperature and high disinfectant levels converge. Guidance on such conditions is given in PIPA POP018. In some cases, a material with a high resistance to disinfectants needs to be used to ensure fitness for purpose. Such materials and pipes are available for the Australian market and are being used where needed.

HOW THE RESIN MANUFACTURER CAN HELP

Resin manufacturers can support pipe manufacturers, contractors and asset owners to demonstrate or verify conformance of the compounds or pipes with the relevant standards through testing. The Qenos Technical Centre in Melbourne is well equipped with a wide variety of physical and chemical analysis techniques. It is accredited by NATA (accreditation numbers 2649 and 1914) for the majority of pipe test methods, including accreditation to ISO standards for resistance to internal pressure ISO 1167, long term hydrostatic strength ISO 9080, slow crack growth ISO 13479, and many others. Experienced technical service specialists at the Technical Centre can also analyse field samples to identify the resin used to make a pipe or assist in failure analysis.

REFERENCES

1. S. Deveci, N. Preschilla, B. Eryigit, *“Effect of carbon black distribution on post yield deformation properties of polyethylene pipes for water transport”,* OzPipe XIX, Sydney, 7-8 November 2019
2. https://blog.greencarrier.com/container-rain-what-it-is-and-how-to-prevent-moisture-damage/
3. J. Wassenaar, P. Micic, “The Next Generation PE Pipe Resin”, Qenos White Paper, November 2017. Available for download via www.qenos.com.
4. Plastic Pipes Industry Association of Australia (PIPA), *“POP004 Polyethylene Pipe and Fittings Compounds”,* Industry Guideline, Issue 22, May 2020. Available for download via www.pipa.com.au

Qenos | Ingenious Transformations

Disclaimer

Qenos Pty Ltd

471 Kororoit Creek Rd
Altona Victoria 3018 Australia

Phone 1800 063 573
ABN 62 054 196 771

–

qenos.com